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(54) **SYSTEMS FOR MEASURING PROPERTIES OF WATER IN A WATER DISTRIBUTION SYSTEM**

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None
See application file for complete search history.

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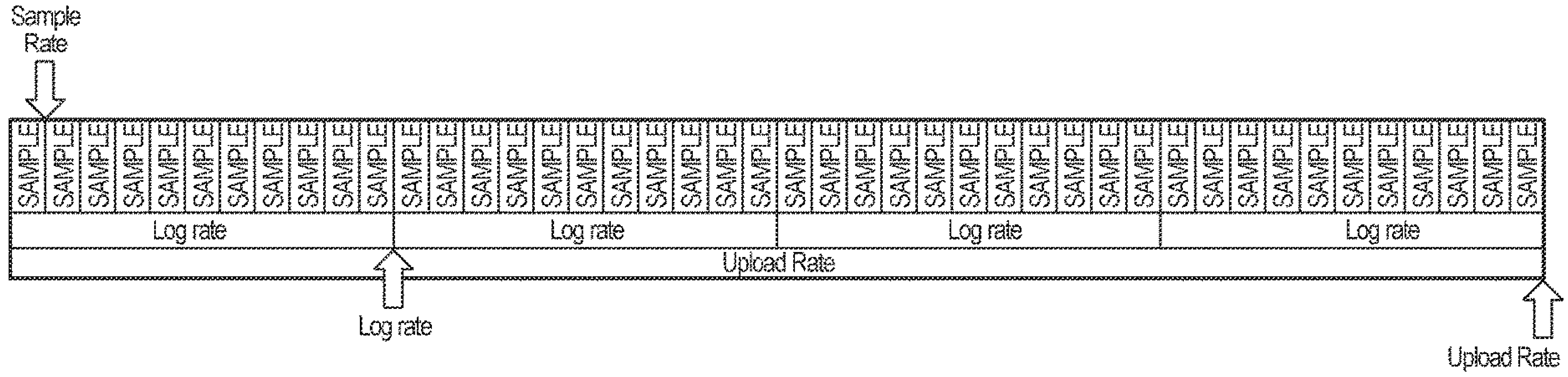
(57) **ABSTRACT**

Systems and methods of measuring properties of water in a water distribution system are provided. An analysis system, according to one embodiment, comprises a plurality of water sensors connected at various points to the water distribution system, each of the plurality of water sensors configured to measure a property of water. The analysis system also includes a computer server configured to communicate with the plurality of water sensors via a network and receive water measurement data from the plurality of water sensors. The computer server comprises a processor, a database configured to store the water measurement data, and a system health monitoring module configured to evaluate the health of the water distribution system to obtain health data. The analysis system further includes at least one client device configured to communicate with the computer server via the network and receive the health data from the computer server.

19 Claims, 20 Drawing Sheets



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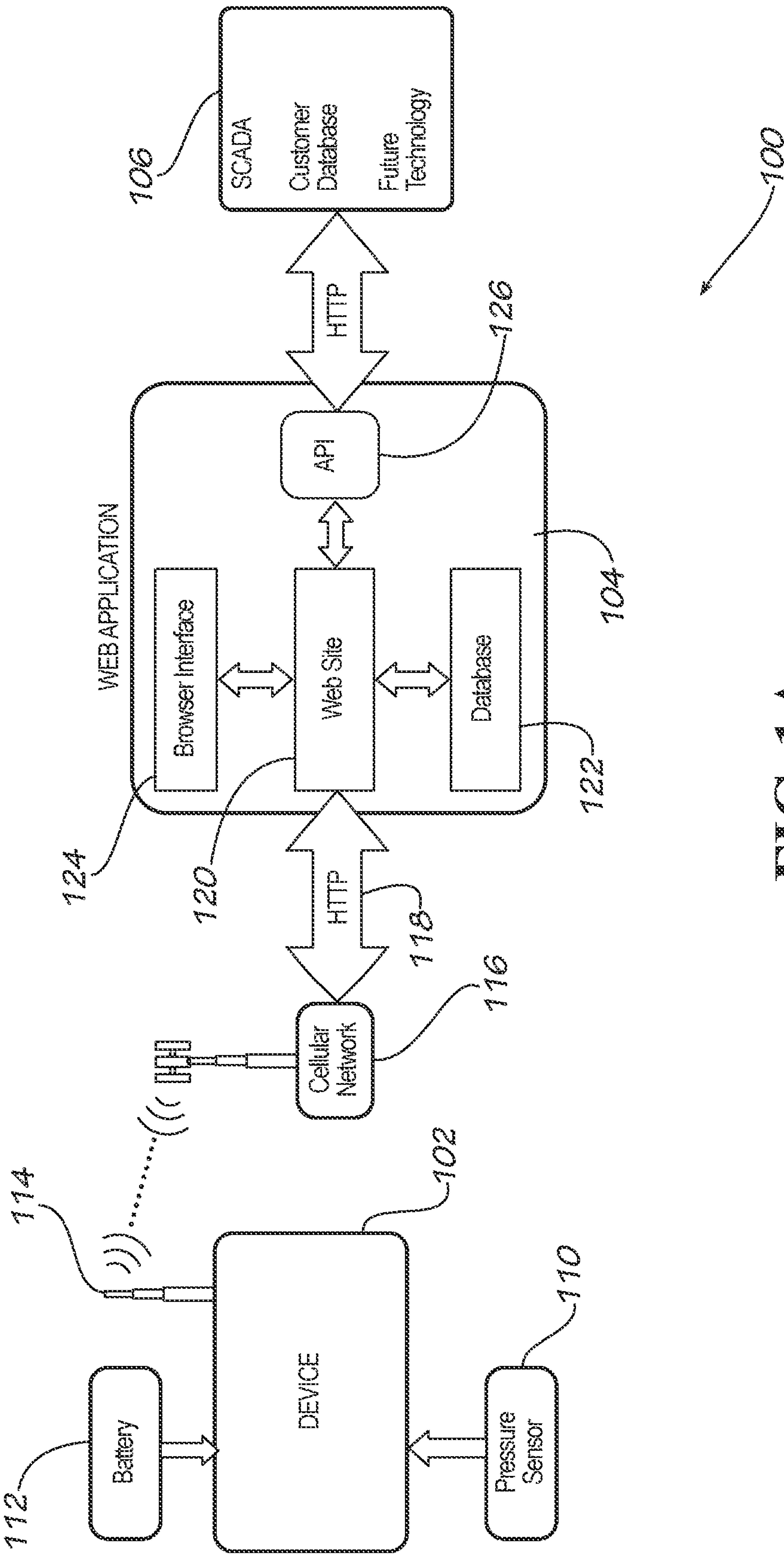
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FIG. 1A

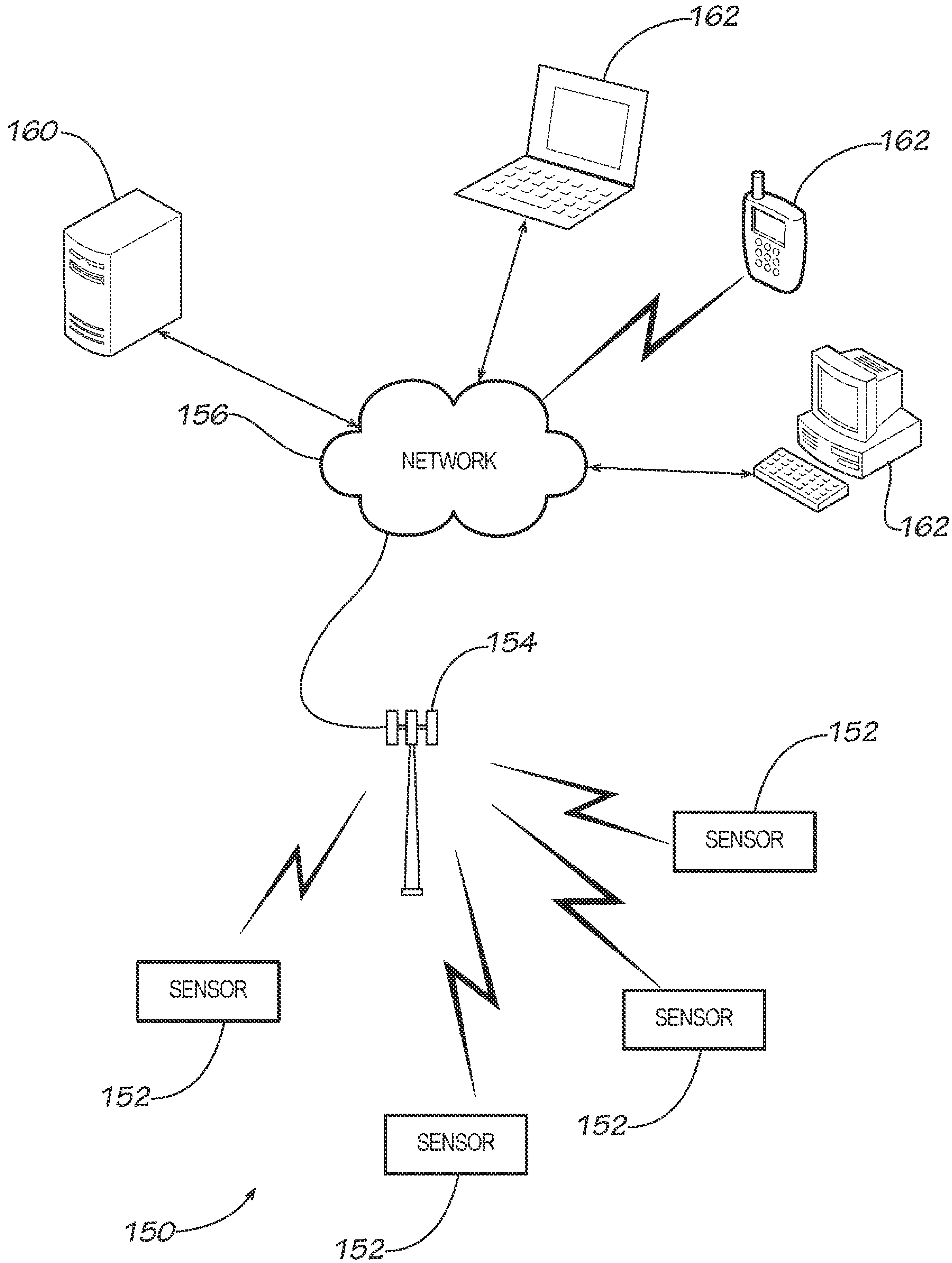
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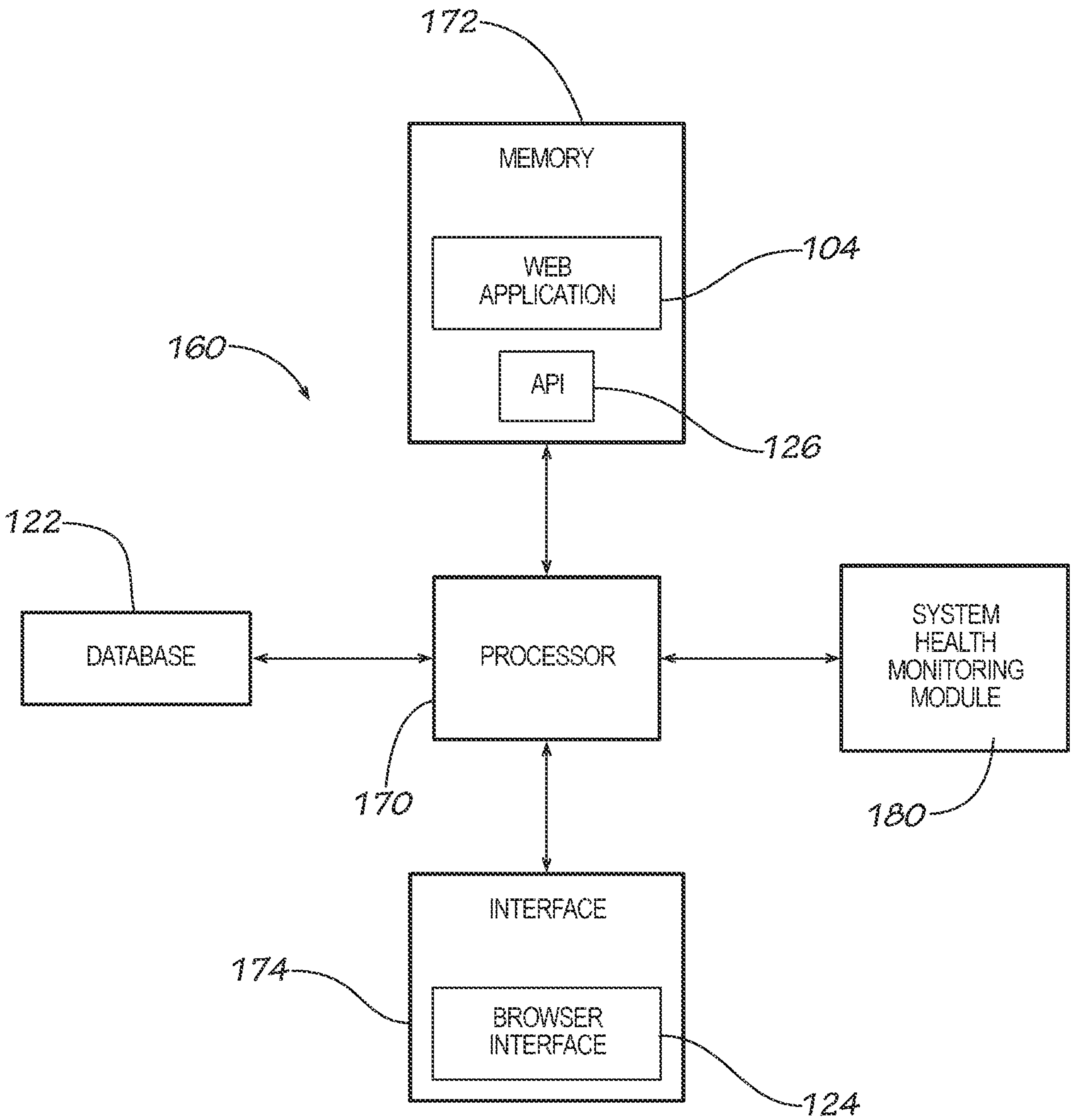
FIG. 1B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INTERFACE
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BROWSER INTERFACE
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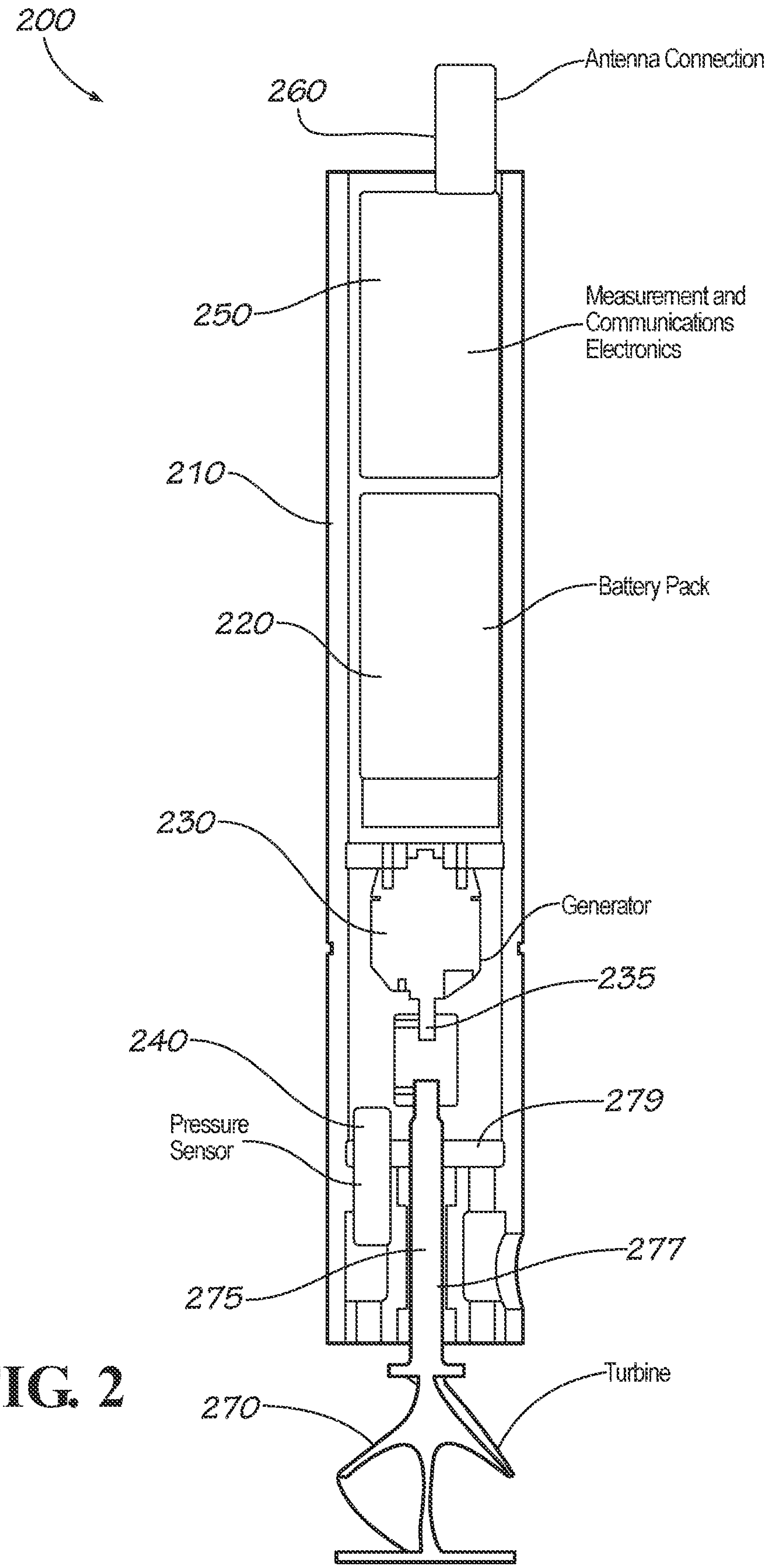
FIG. 1C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Turbine

FIG. 2

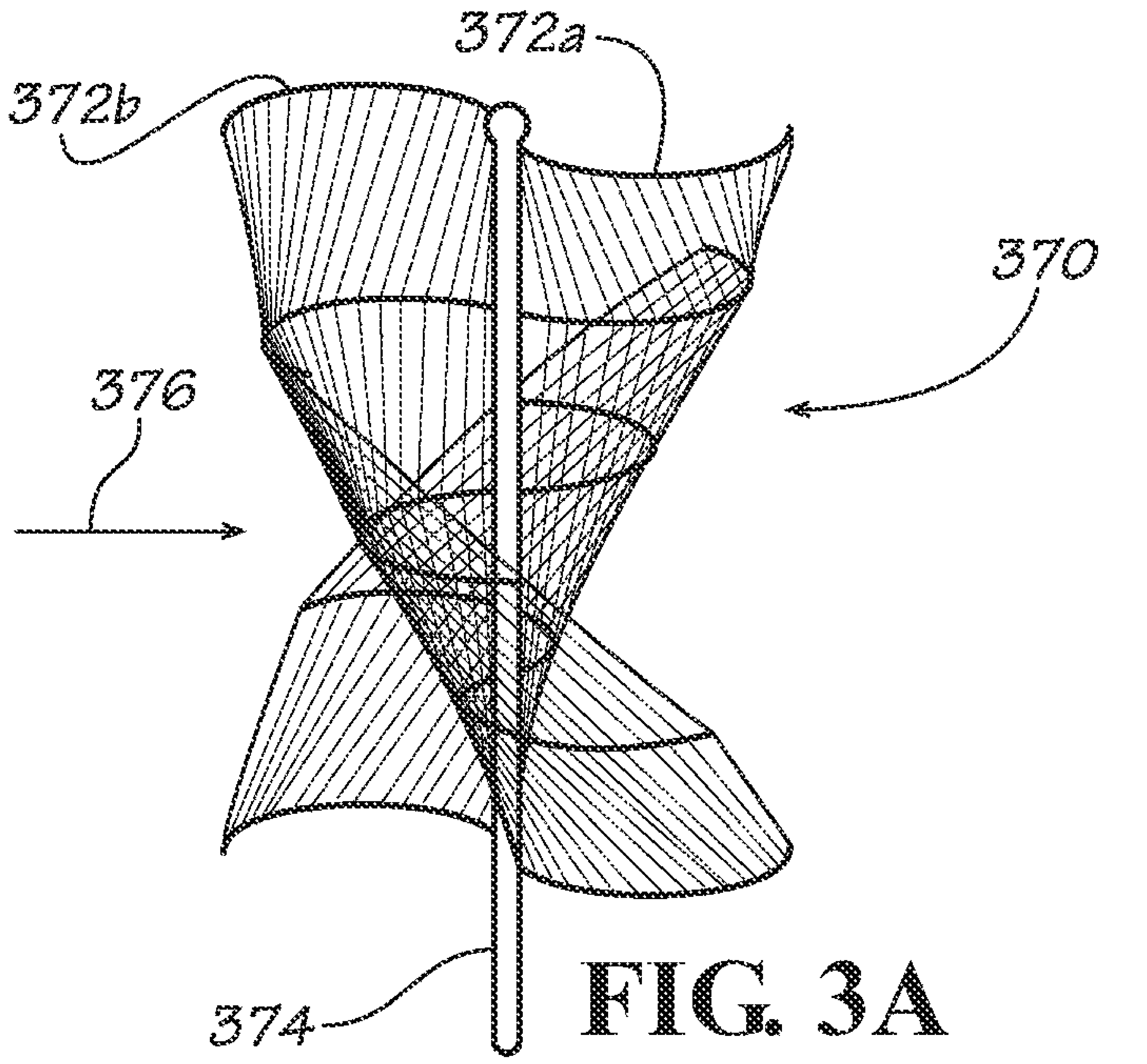

FIG. 3A

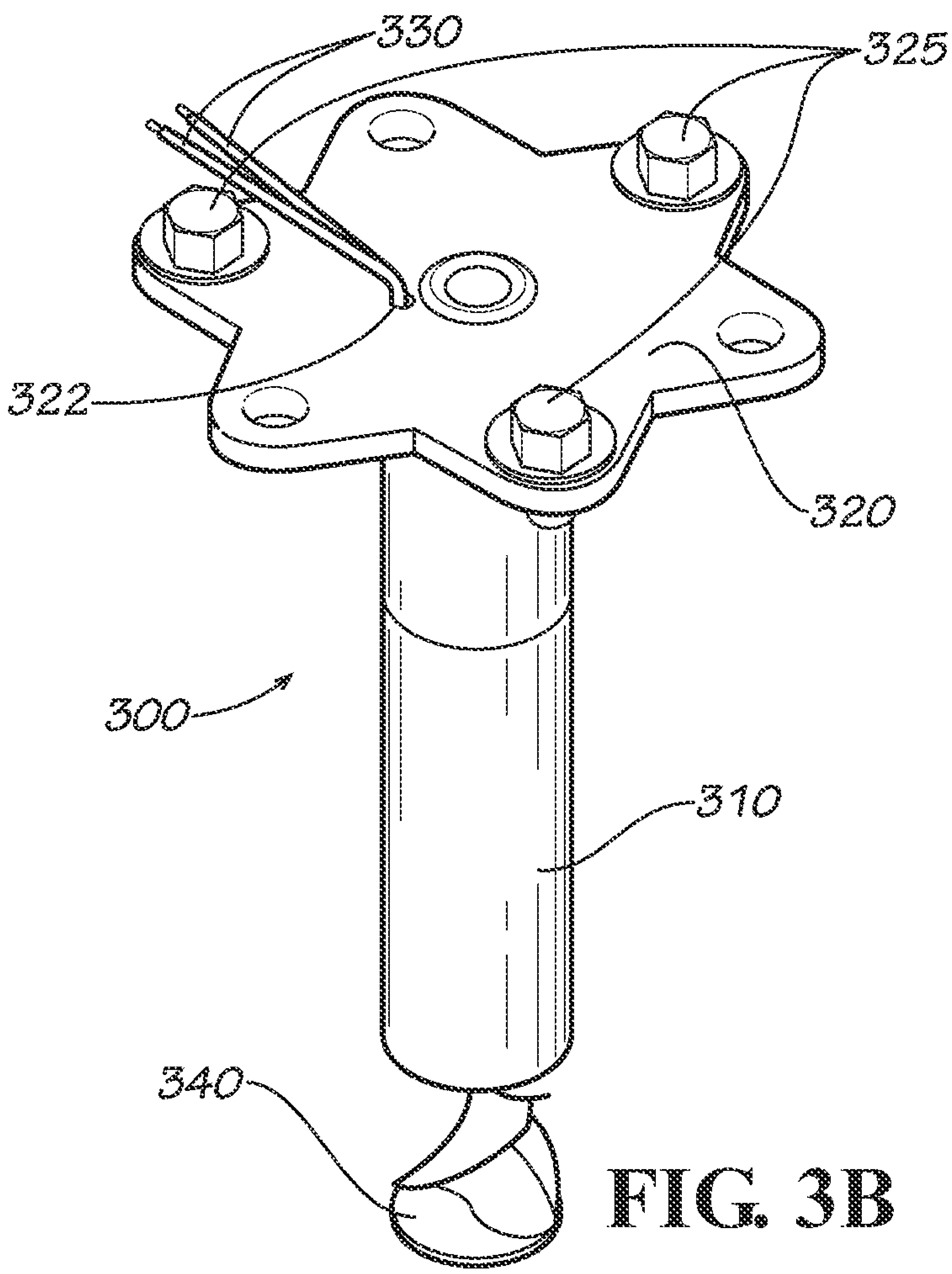

FIG. 3B

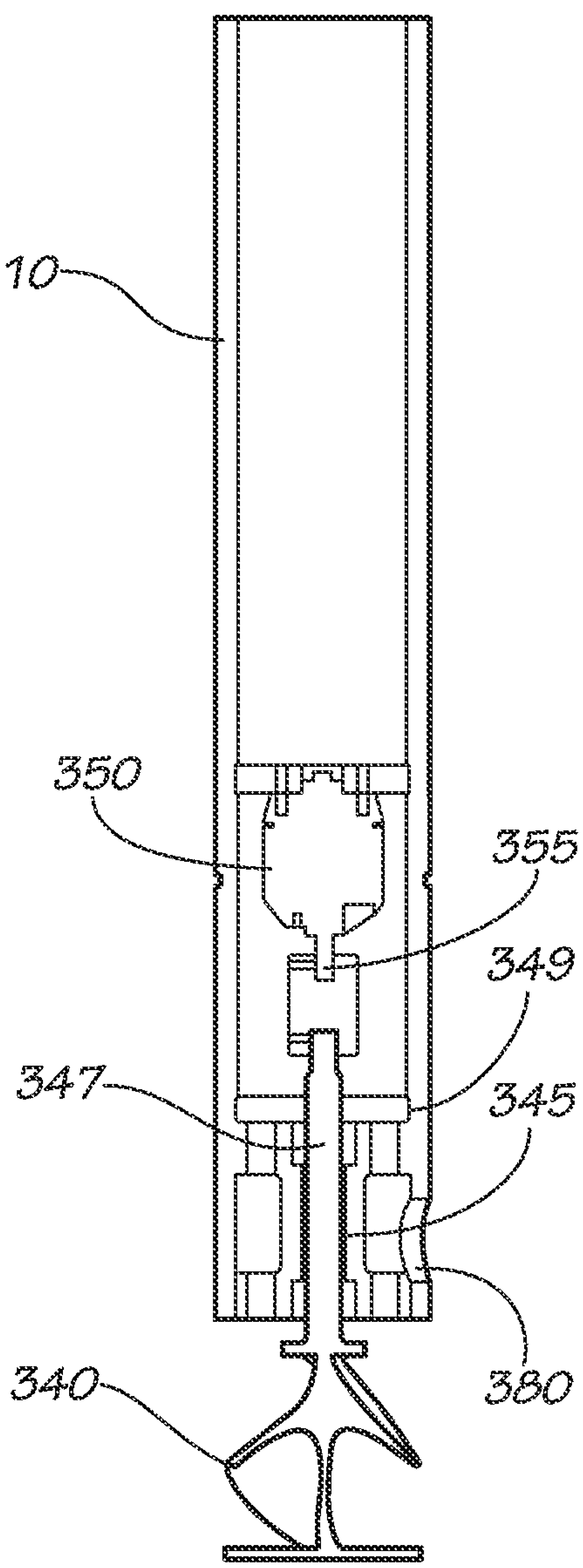

FIG. 3C

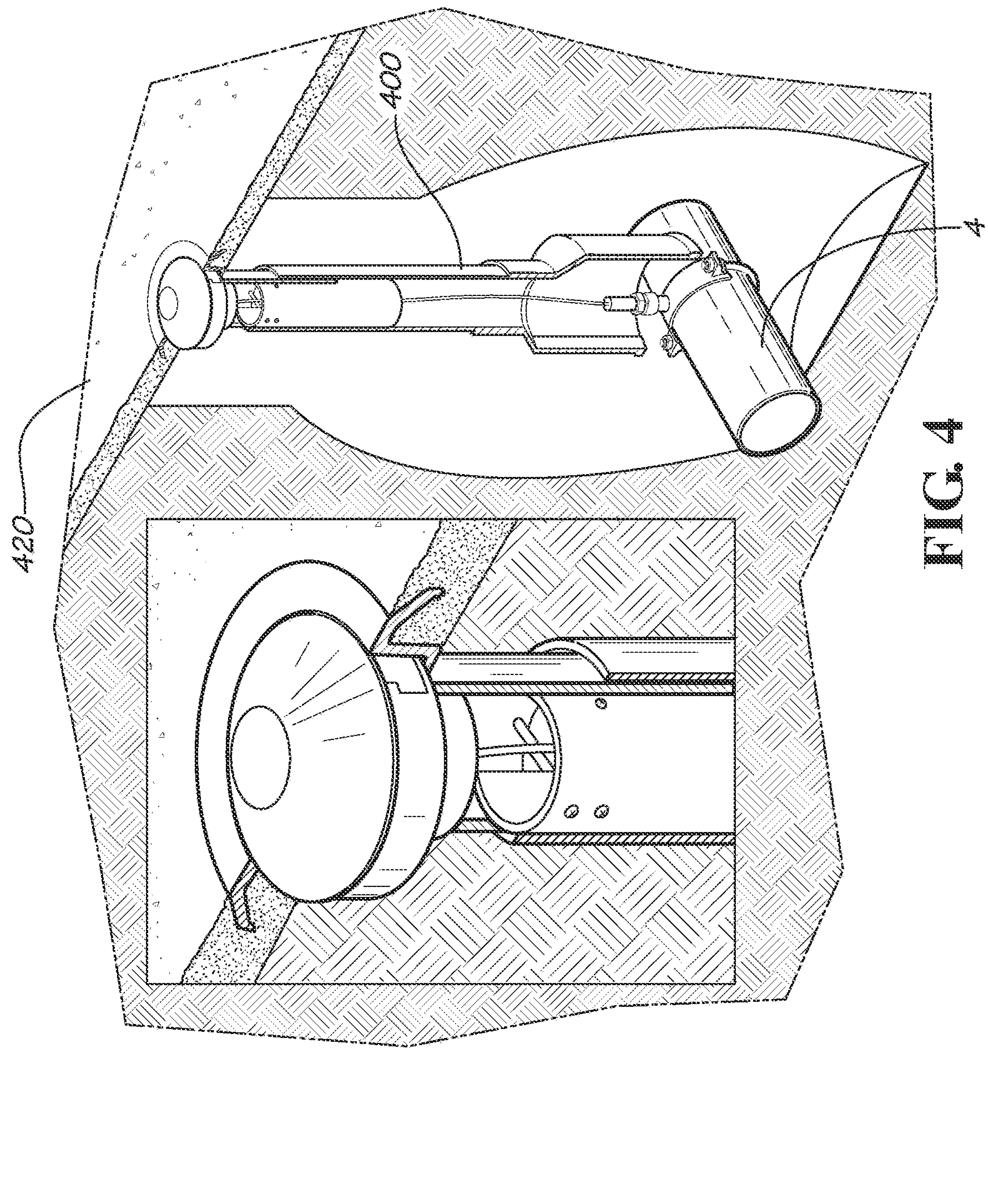

FIG. 4

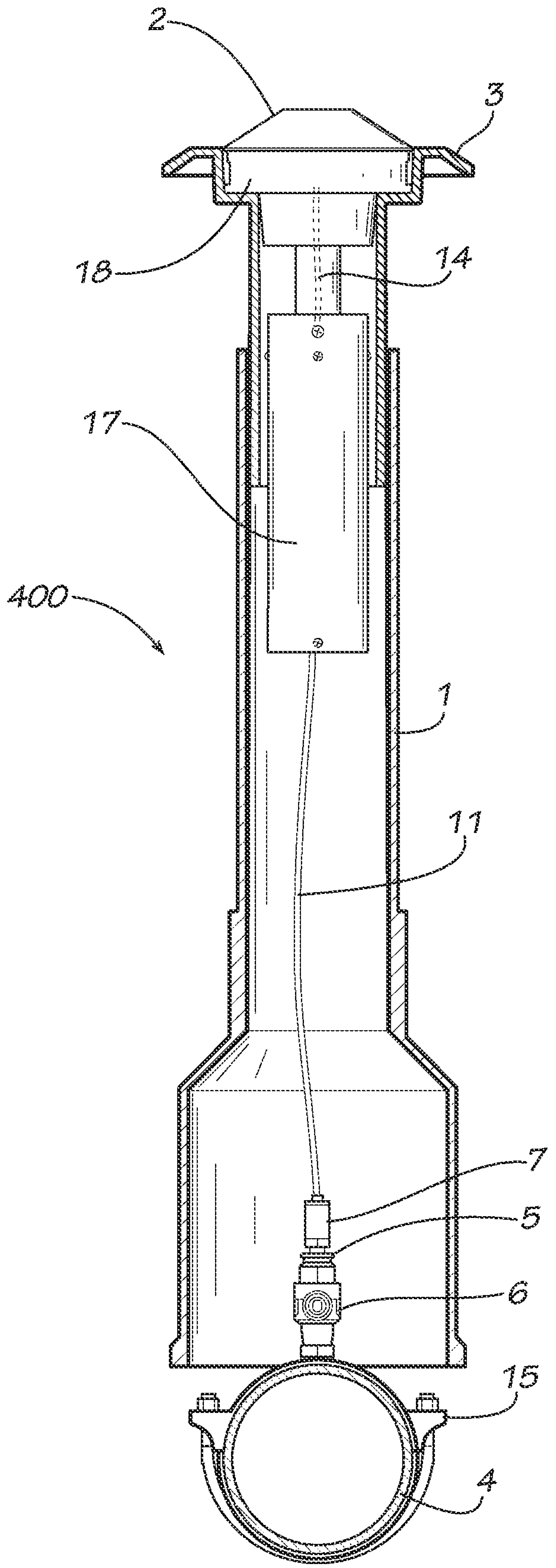

FIG. 5

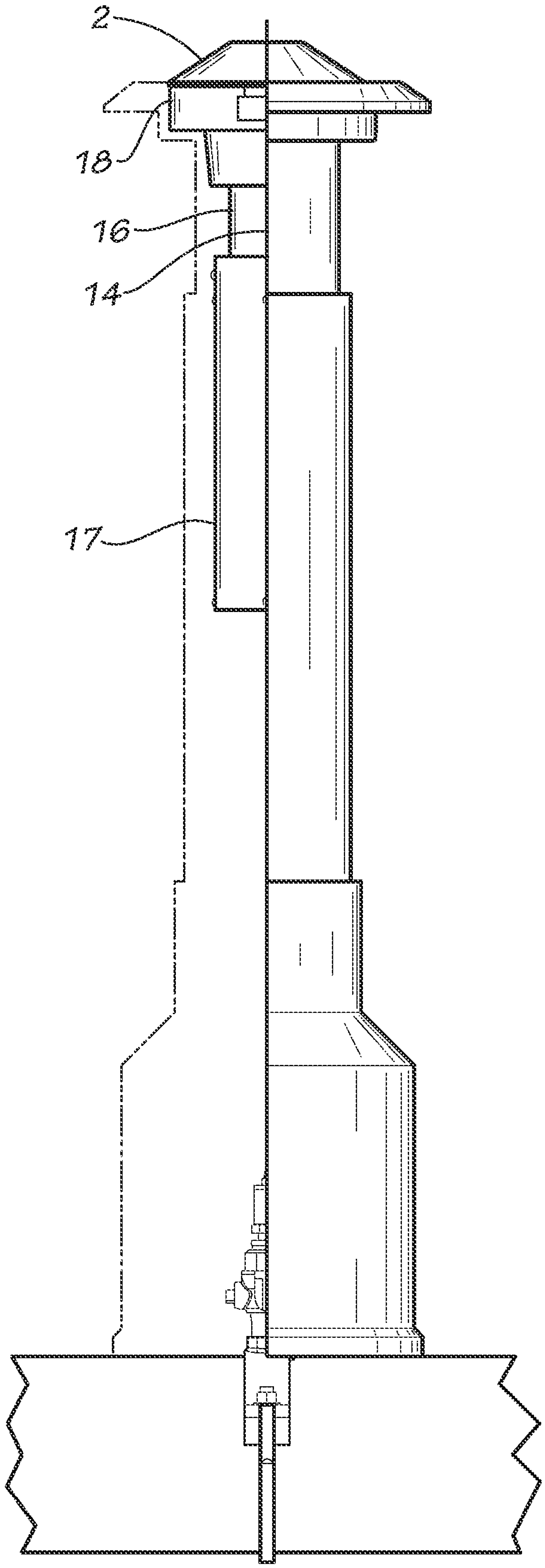

FIG. 6

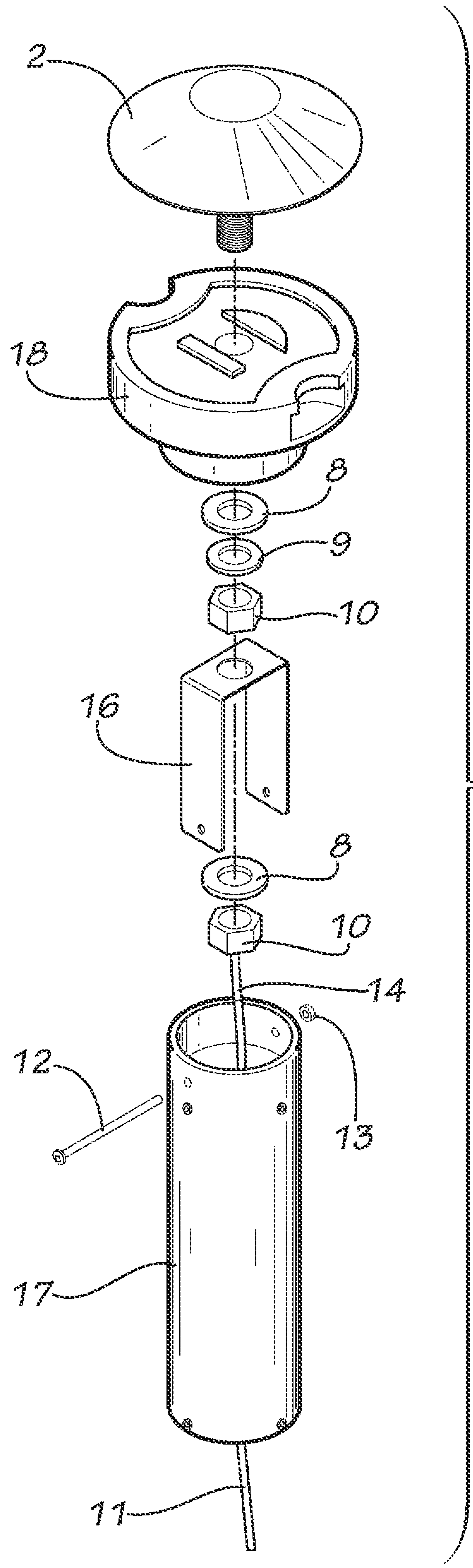

FIG. 7

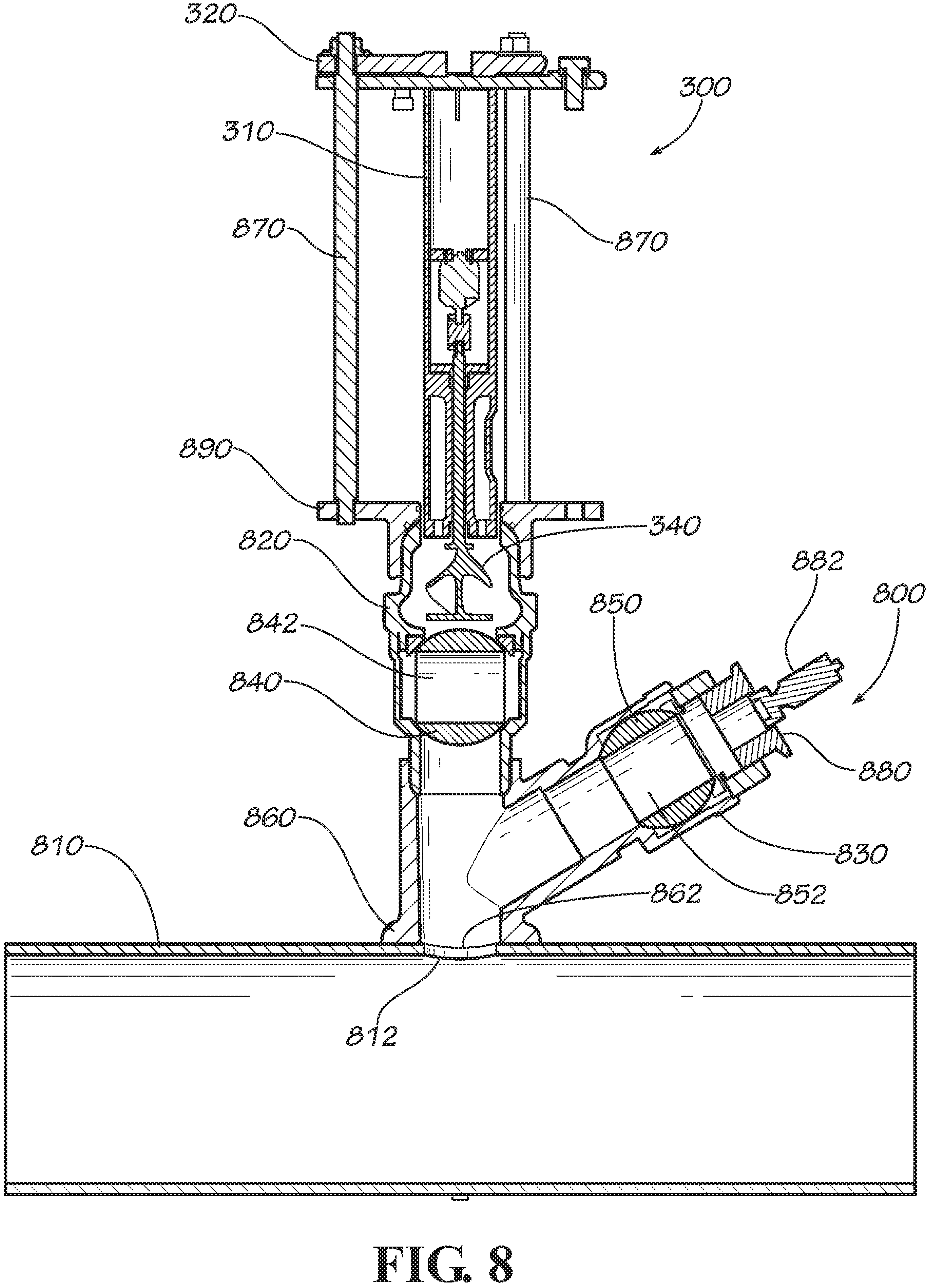
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FIG. 8

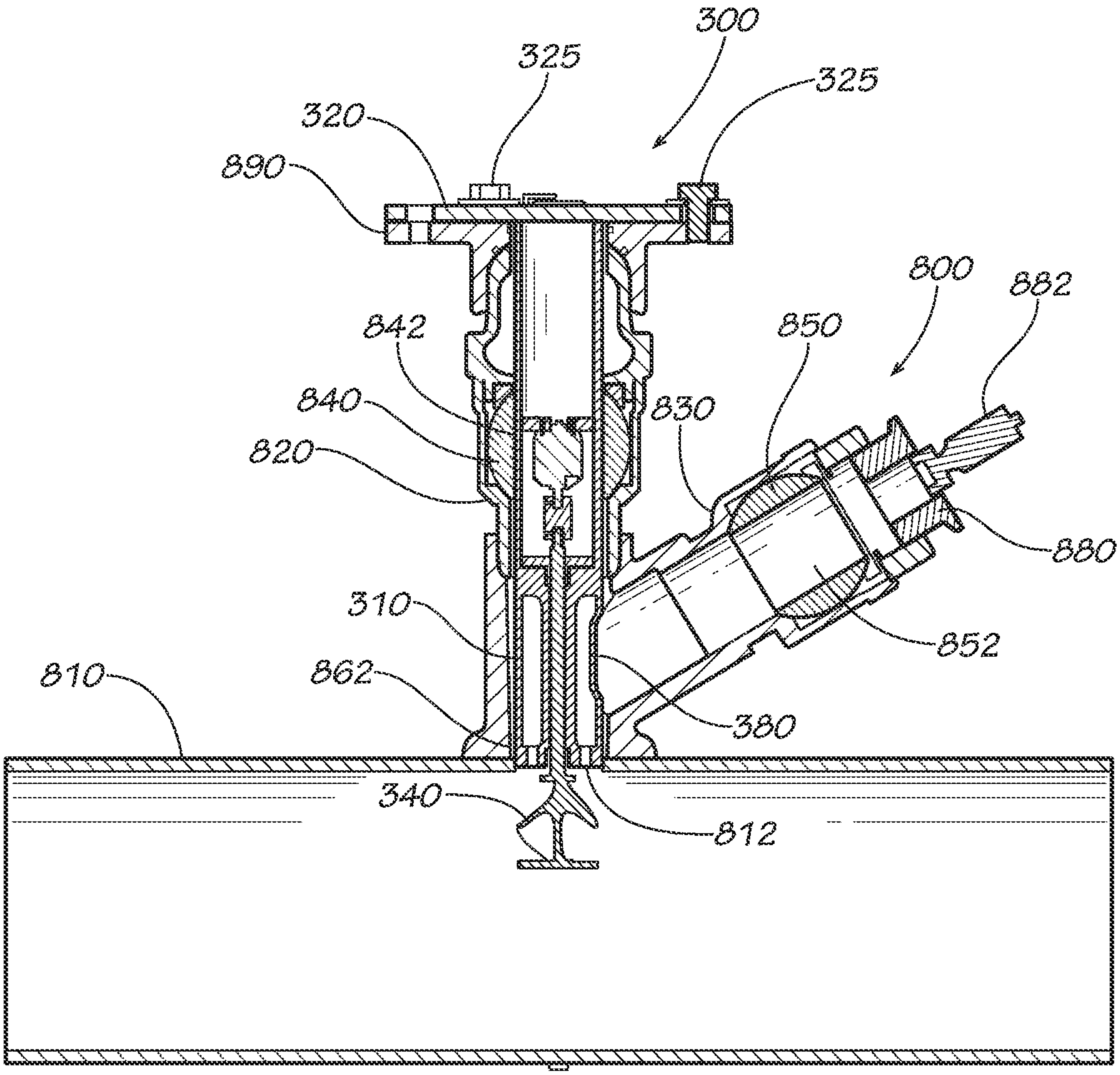

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FIG. 9

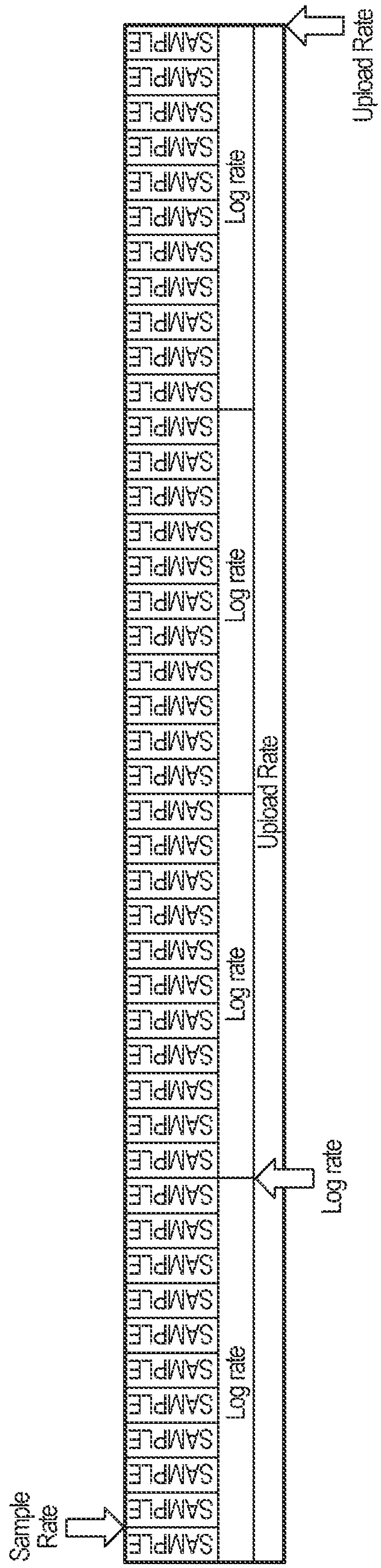
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FIG. 10

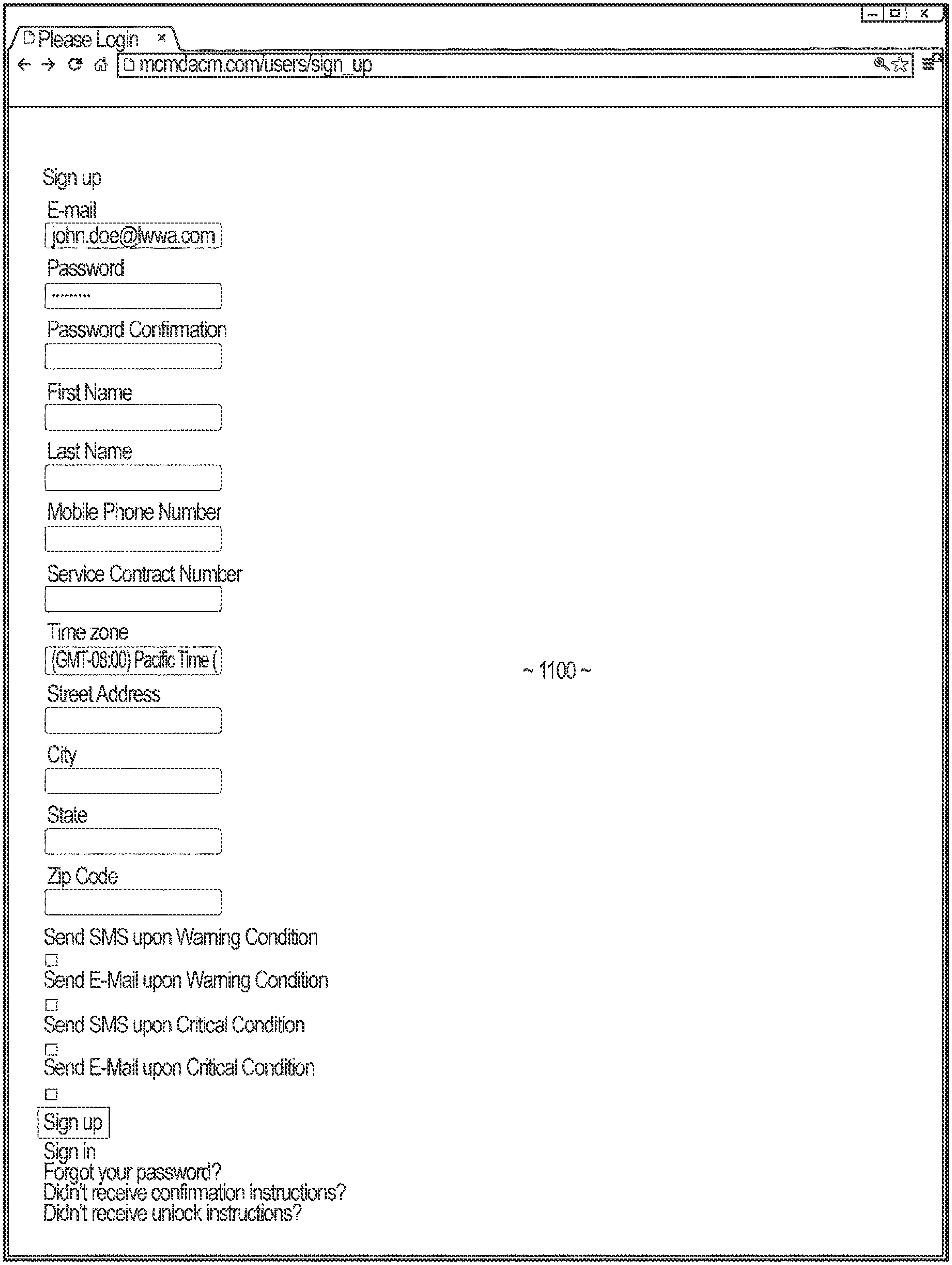
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FIG. 11

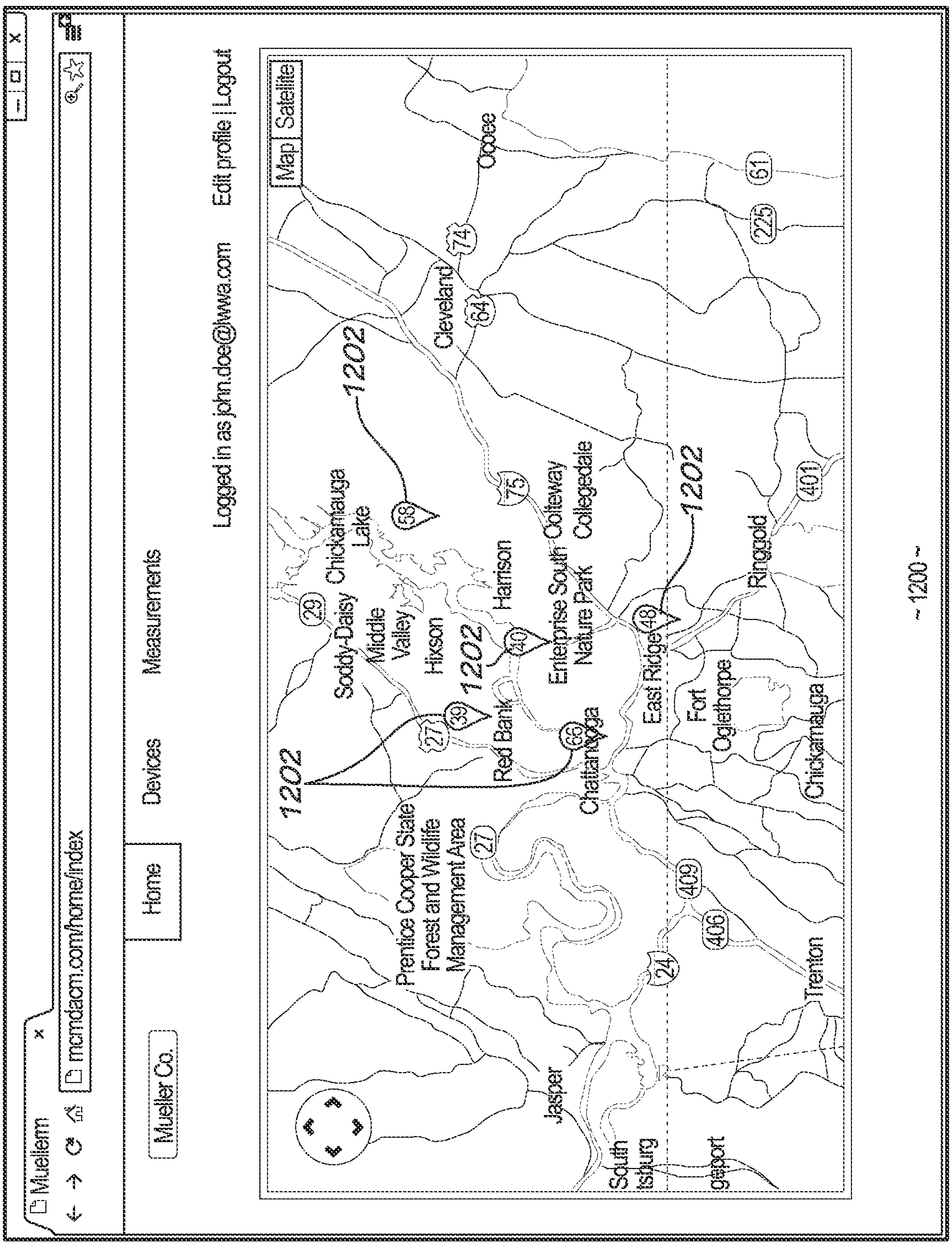
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FIG. 12

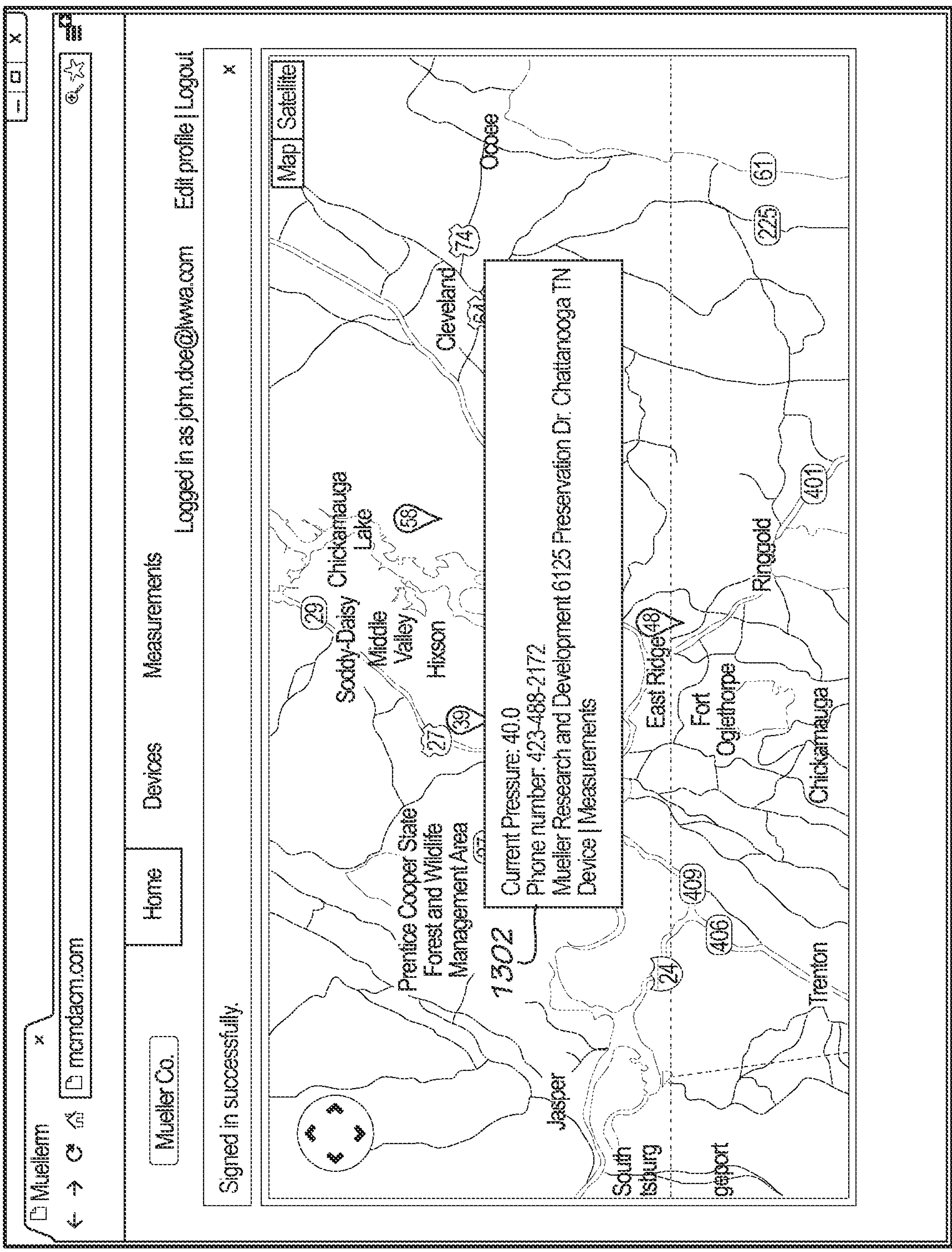
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FIG. 13

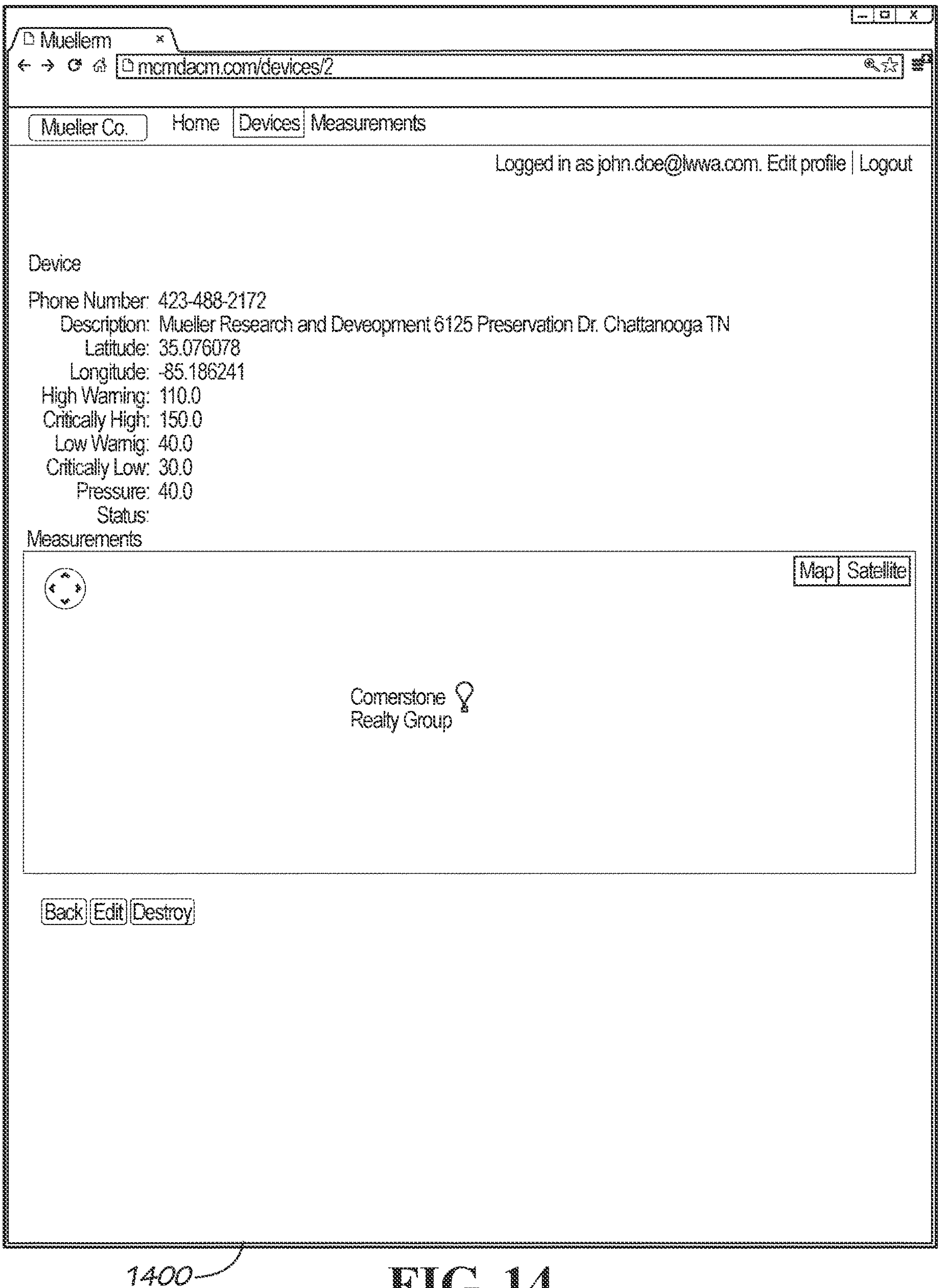
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FIG. 14

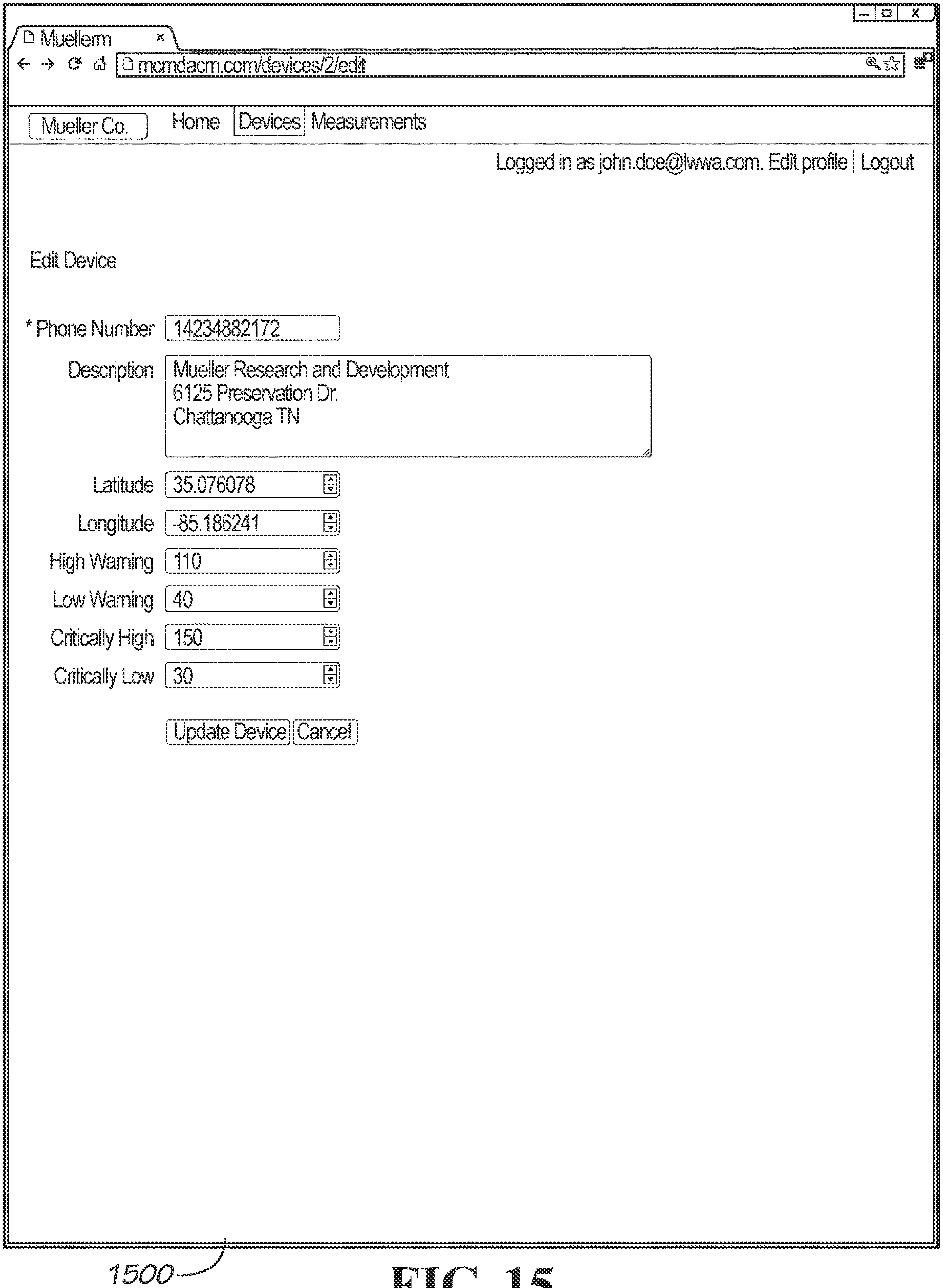
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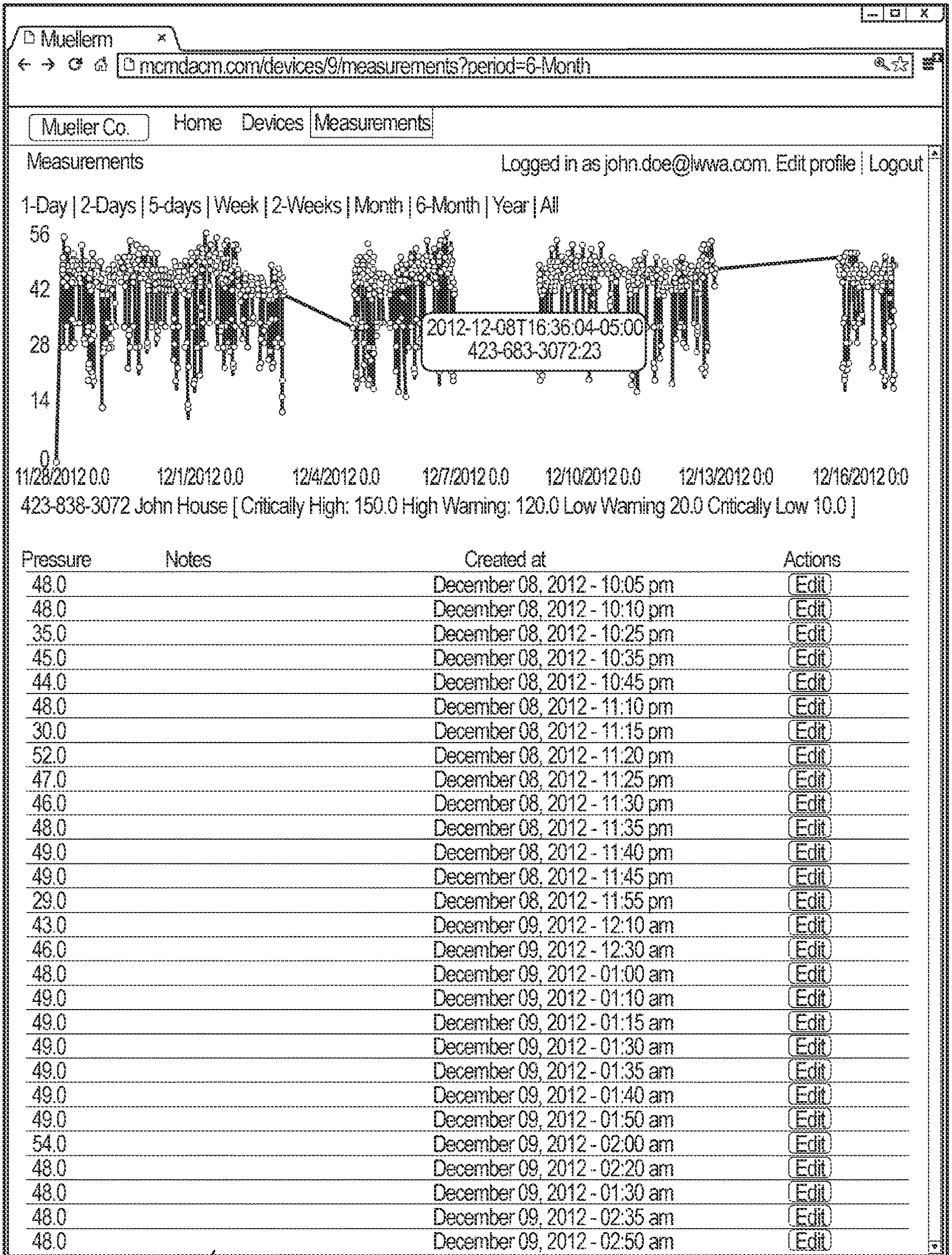
FIG. 15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12/1/2012 0.0
12/4/2012 0.0
12/7/2012 0.0
12/10/2012 0.0
12/13/2012 0:0
12/16/2012 0:0
423-838-3072 John House [Critically High: 150.0 High Warning: 120.0 Low Warning 20.0 Critically Low 10.0]
Pressure
Notes
Created at
Actions
48.0 December 08, 2012 - 10:05 pm Edit
48.0 December 08, 2012 - 10:10 pm Edit
35.0 December 08, 2012 - 10:25 pm Edit
45.0 December 08, 2012 - 10:35 pm Edit
44.0 December 08, 2012 - 10:45 pm Edit
48.0 December 08, 2012 - 11:10 pm Edit
30.0 December 08, 2012 - 11:15 pm Edit
52.0 December 08, 2012 - 11:20 pm Edit
47.0 December 08, 2012 - 11:25 pm Edit
46.0 December 08, 2012 - 11:30 pm Edit
48.0 December 08, 2012 - 11:35 pm Edit
49.0 December 08, 2012 - 11:40 pm Edit
49.0 December 08, 2012 - 11:45 pm Edit
29.0 December 08, 2012 - 11:55 pm Edit
43.0 December 09, 2012 - 12:10 am Edit
46.0 December 09, 2012 - 12:30 am Edit
48.0 December 09, 2012 - 01:00 am Edit
49.0 December 09, 2012 - 01:10 am Edit
49.0 December 09, 2012 - 01:15 am Edit
49.0 December 09, 2012 - 01:30 am Edit
49.0 December 09, 2012 - 01:35 am Edit
49.0 December 09, 2012 - 01:40 am Edit
49.0 December 09, 2012 - 01:50 am Edit
54.0 December 09, 2012 - 02:00 am Edit
48.0 December 09, 2012 - 02:20 am Edit
48.0 December 09, 2012 - 01:30 am Edit
48.0 December 09, 2012 - 02:35 am Edit
48.0 December 09, 2012 - 02:50 am Edit

1600

FIG. 16

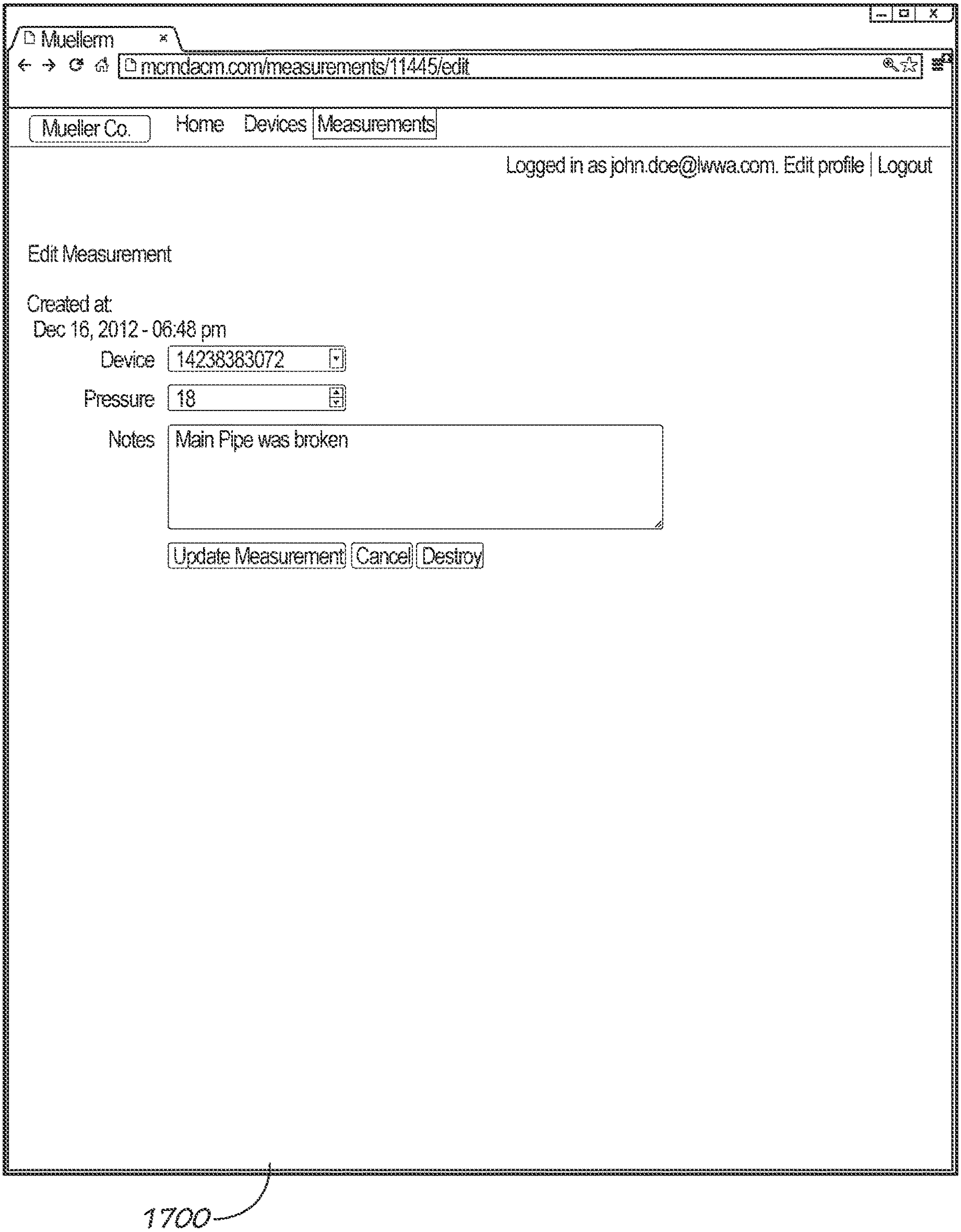
Muellerm
mcmdacm.com/measurements/11445/edit
Mueller Co.
Home
Devices
Measurements
Logged in as john.doe@lwwa.com. Edit profile | Logout
Edit Measurement
Created at:
Dec 16, 2012 - 06:48 pm
Device
14238383072
Pressure
18
Notes
Main Pipe was broken
Update Measurement
Cancel
Destroy
1700

FIG. 17

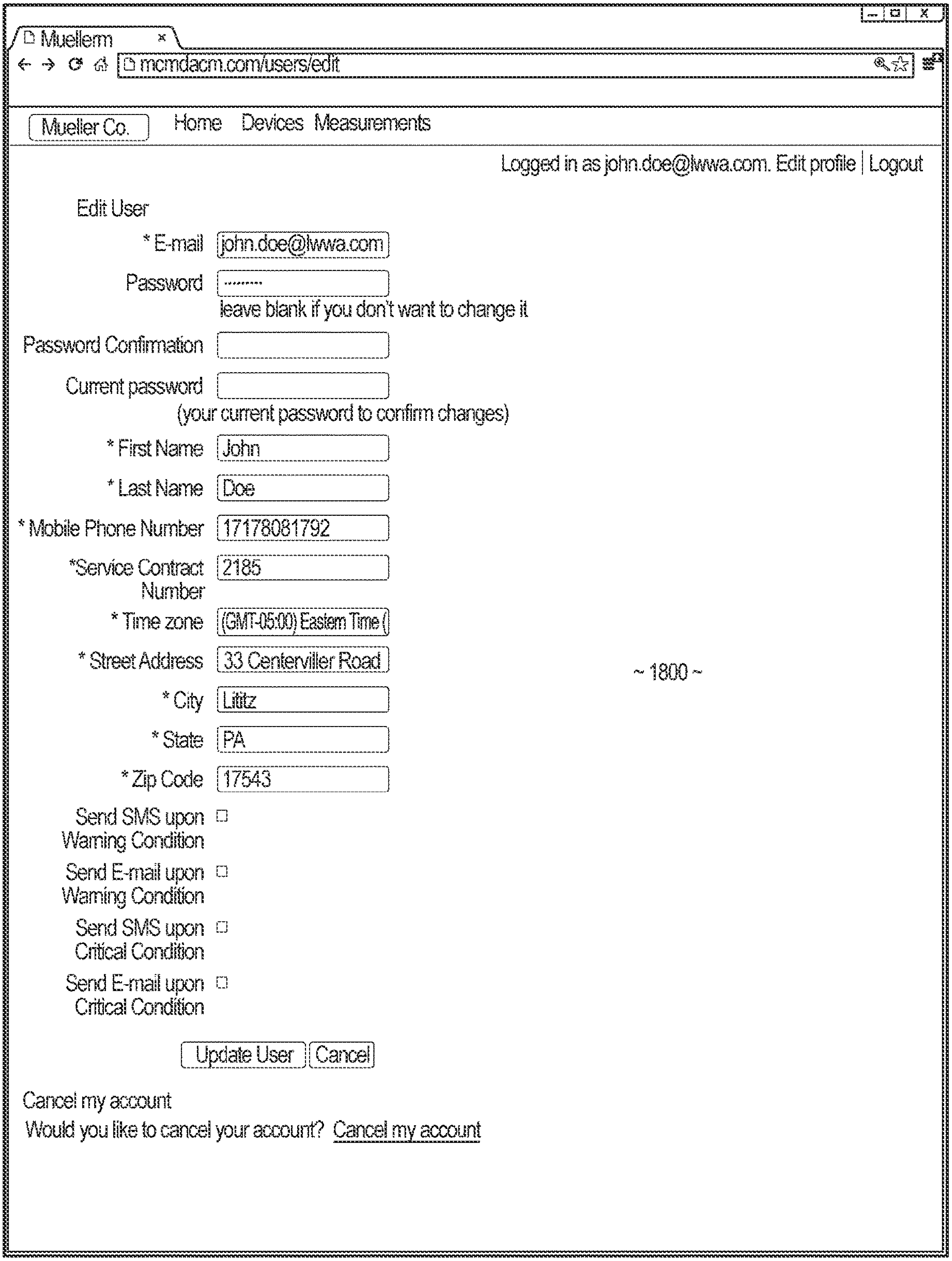
Muellerm
mcmdacm.com/users/edit
Mueller Co.
Home
Devices
Measurements
Logged in as john.doe@lwwa.com. Edit profile | Logout
Edit User
* E-mail
john.doe@lwwa.com
Password
leave blank if you don't want to change it
Password Confirmation
Current password
(your current password to confirm changes)
* First Name
John
* Last Name
Doe
* Mobile Phone Number
17178081792
*Service Contract Number
2185
* Time zone
(GMT-05:00) Eastern Time (
* Street Address
33 Centerviller Road
* City
Lititz
* State
PA
* Zip Code
17543
Send SMS upon Warning Condition
Send E-mail upon Warning Condition
Send SMS upon Critical Condition
Send E-mail upon Critical Condition
Update User
Cancel
Cancel my account
Would you like to cancel your account? Cancel my account
~ 1800 ~

FIG. 18

SYSTEMS FOR MEASURING PROPERTIES OF WATER IN A WATER DISTRIBUTION SYSTEM

REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/209,257, filed on Mar. 13, 2014, which claims the benefit of U.S. Provisional Application No. 61/794,616, filed Mar. 15, 2013, both of which are hereby specifically incorporated by reference herein in their entireties.

TECHNICAL FIELD

The present disclosure generally relates to water distribution systems, and more particularly relates to measuring properties of water in a water distribution system and managing the measurement data.

BACKGROUND

Water utility companies provide water to customers through a network of water pipes. This network of pipes can be referred to as a water distribution system.

SUMMARY

The present disclosure provides systems and methods for measuring properties of water in a water distribution system. In various embodiments, a non-transitory web application is stored on a computer-readable medium, wherein the web application comprises web site logic, browser interface logic, an application programming interface, and a database. The web site logic is configured to maintain a web site having at least one web page. The browser interface logic is configured to enable a remote device to access the at least one web page. The application programming interface is configured to interface with the remote device to enable the remote device to access the web application. The database is configured to store water data related to a plurality of water measurements. The web site logic is further configured to receive a data request from the remote device, search the database in response to the data request to obtain at least one water measurement, and send the at least one water measurement to the remote device.

In addition, according to various embodiments of the present disclosure, an analysis system is provided. The analysis system comprises a plurality of water sensors connected at various points to a water distribution system, each of the plurality of water sensors configured to measure a property of water. The analysis system also includes a computer server configured to communicate with the plurality of water sensors via a network and receive water measurement data from the plurality of water sensors. The computer server comprises a processor, a database configured to store the water measurement data, and a system health monitoring module configured to evaluate the health of the water distribution system to obtain health data. The analysis system further includes at least one client device configured to communicate with the computer server via the network and receive the health data from the computer server.

In addition, in various embodiments, a water sensing assembly is disclosed. The water sensing assembly comprises a valve box securely mountable on an underground water pipe. The water sensing assembly also includes a

sensor mounted inside the valve box, wherein the sensor is configured to sense a property of water within the underground water pipe. Also included is a top section connected to the valve box. An electrical communication device is mounted at a top portion of the adjustable top section such that the electrical communication device is positioned at or near the surface of the ground.

A service saddle is also provided, wherein the service saddle comprises a lower channel alignable with a bore in a water pipe. The service saddle also includes a main port having an interior volume opened to the lower channel and a secondary port having an interior volume opened to the lower channel. The service saddle further includes a first valve moveably mounted in the main port for controlling water flow through the main port and a second valve moveably mounted in the secondary port for controlling water flow through the secondary port.

In addition, in various embodiments, another water sensing assembly is disclosed. The water sensing assembly is mountable on a water pipe and comprises a sensor, a generator, and a turbine coupled to the turbine and positionable through a bore in the water pipe into water flow within the water pipe.

The present disclosure also describes a method of sensing a property of water within a water distribution system. The method comprises a step of periodically sampling water within a water distribution system according to a sampling rate such that multiple water samples are obtained during each of at least one predefined logging interval. The method also includes the steps of measuring a property of the water for each of the multiple water samples and storing a maximum of two values of the measured property for each predefined logging interval, wherein the two values include a highest value measured and a lowest value measured.

Various implementations described in the present disclosure may include additional systems, methods, features, and advantages, which may not necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. Corresponding features and components throughout the figures may be designated by matching reference characters for the sake of consistency and clarity.

FIG. **1**A is a block diagram illustrating a system for measuring properties of water in a water distribution system and managing the measurement data, according to various embodiments of the present disclosure.

FIG. **1**B is a block diagram illustrating a system for measuring properties of water and managing the measurement data, according to various embodiments of the present disclosure.

FIG. **1**C is a block diagram illustrating the server shown in FIG. **1**B, according to various embodiments of the present disclosure.

FIG. **2** is a cutaway side view of a water sensing assembly, according to various embodiments of the present disclosure.

FIG. **3**A is perspective detail view of the shape of a vertical axis turbine, according to various embodiments of the present disclosure.

FIG. **3**B is a perspective view of a second water sensing assembly, according to various embodiments of the present disclosure.

FIG. **3**C is cutaway side view of the second water sensing assembly of FIG. **3**B, according to various embodiments of the present disclosure.

FIG. **4** is a diagram of a third water sensing assembly installed on a pipe, according to various embodiments of the present disclosure.

FIG. **5** is front cross-sectional view of the third water sensing assembly of FIG. **4**, according to various embodiments of the present disclosure.

FIG. **6** is a partial cross-sectional side view of the third water sensing assembly of FIG. **4**, according to various embodiments of the present disclosure.

FIG. **7** is an exploded view of a communication assembly of the third water sensing assembly of FIG. **4**, according to various embodiments of the present disclosure.

FIG. **8** is a cutaway side view of a water sensing assembly of FIG. **3**B in a multi-port service saddle, according to various embodiments of the present disclosure.

FIG. **9** is a cutaway side view of the second water sensing assembly of FIG. **3**B in the multi-port service saddle of FIG. **8** in a power generation mode, according to various embodiments of the present disclosure.

FIG. **10** is a chart showing sampling rate, log rate, and upload rate, according to various embodiments of the present disclosure.

FIG. **11** is a screen view of a user interface for enabling a user to sign in with a server, according to various embodiments of the present disclosure.

FIG. **12** is a screen view of a user interface showing a map of the locations of installed sensors, according to various embodiments of the present disclosure.

FIG. **13** is a screen view of a user interface showing the map of FIG. **12** with information about a sensing device superimposed, according to various embodiments of the present disclosure.

FIG. **14** is a screen view of a user interface showing further details of a sensing device, according to various embodiments of the present disclosure.

FIG. **15** is a screen view of a user interface for enabling a user to edit parameters of a sensing device, according to various embodiments of the present disclosure.

FIG. **16** is a screen view of a user interface showing a graph and a table of measurements logged by a sensing device, according to various embodiments of the present disclosure.

FIG. **17** is a screen view of a user interface for enabling a user to edit measurements, according to various embodiments of the present disclosure.

FIG. **18** is a screen view of a user interface for enabling a user to edit user information, according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

The present disclosure describes systems and methods for measuring properties of water within a water distribution system at multiple locations throughout the water distribution system. The present disclosure also describes sensors that may be installed in the water distribution system for one or more clients (e.g., water utility companies). The sensors may be configured to generate energy from the water itself to power its internal circuitry. The sensors may be tapped into the side of a pipe or installed at any location in the system.

The water property measurements may be logged in the sensors and periodically uploaded to a server using a wireless communication network. Measurements may also be uploaded on demand in some embodiments. The server, which may be a web server, maintains the measurements in a database. Clients may access the measurements to view the readings during various time periods. Also, the clients may request a substantially real-time measurement.

FIG. **1**A is a block diagram illustrating an embodiment of a system **100** for managing data related to properties of water in a water distribution system. As shown in this implementation, the system **100** comprises a sensing device **102**, a web application **104**, and a client system **106**. It may be noted that, as illustrated, the system **100** includes a single sensing device **102** and a single client system **106**. However, it will be understood by one of skill in the art that the system **100** may include any number of sensing devices **102** installed in various locations in the water distribution system. Also, the system **100** may include any number of client systems **106** for any number of clients. The multiple client systems **106** may be connected to the web application **104** through a communication network. In this respect, multiple sensing devices **102** may be used to monitor water properties at various locations within one or more water distribution systems for multiple clients, and the clients can access their respective sensor readings through the web application **104**.

The sensing device **102** of the current embodiment comprises, among other things, a sensor **110** (e.g., a pressure sensor), a battery **112**, and an antenna **114**. The sensing device **102** may include any suitable type of sensor **110** for sensing various characteristics of water within a water distribution system. For example, the sensor **110** may be a pressure sensor for measuring water pressure at a particular location in the water distribution system, a flow rate sensor for measuring the rate that water is flowing through the particular location of the water distribution system, a chlorine sensor for measuring the chlorine content of the water at the location, or other types of sensors.

The battery **112** may include any suitable type of battery or batteries for providing power to the sensor **110** and other electronics of the sensing device **102**. In some embodiments, the sensing device **102** may include a power generation device that harvests energy from the flow of water. The power generation device may be configured to recharge the battery **112**, supplement the power of the battery **112**, or even replace the battery **112**.

The antenna **114** is configured to wirelessly transmit properties of water that are sensed by the sensing device **102** to the web application **104**. The sensor data may be transmitted over any suitable type of wireless network **116**, such as, for example, a cellular network, radio frequency (RF) channels, Wi-Fi, Bluetooth, etc. A receiver on the wireless network **116** is configured to convert the sensor data signals to allow transmission over a data network **118** using any suitable protocol, such as the Hypertext Transfer Protocol (http), Transmission Control Protocol (TCP), Internet Protocol (IP), or other communication protocol. The data network **118** may include a wide area network (WAN), such as the Internet, and/or may include local area networks (LANs).

The web application **104** as shown in FIG. **1**A may be configured on a server, such as a web server, or a group of servers. The web application **104** may be associated with a data management company that provides a service to its clients for managing the clients' sensor data. For example, multiple clients (e.g., water distribution companies) may wish to have the data management company monitor the sensor data and then make the data available to the clients as desired. As explained in more detail below, the clients can customize how the water properties for the pipes in their system are to be sensed. They can also customize how the information about the sensor data can be accessed. They can also customize how they will be contacted if the sensor data reveals a warning or critical condition. In FIG. **1**A, only one client system **106** is shown, but it should be understood that multiple client systems **106** may be configured in the system **100** to access the server on which the web application **104** is running.

FIG. **1**B is a block diagram illustrating an embodiment of a system **150** for measuring properties of water and managing the measurement data. According to the embodiment shown in FIG. **1**B, the system **150** includes a plurality of sensing devices **152** that are distributed throughout an area and are installed to be in contact with water within a water distribution system. The sensing devices **152** are installed and put into service to allow them to take measurements of the water at their particular location and wirelessly communicate the measurement data to a cell tower **154** or other wireless communication device for receiving wireless signals, such as a Wi-Fi or Bluetooth receiver. Also, multiple cell towers **154** or receivers may be incorporated in the system **150**.

The system **150** of FIG. **1**B also includes a network **156**, which enables communication from a wireless communication protocol, or other communication channel protocol, to a data network protocol. The network **156** enables the measurement data received by the cell tower **154** to be transmitted to a server **160**. The server **160** may be one or more computer systems for managing the measurements of water properties. The server **160** may be a web server for providing a web site for clients to access if authorized. The system **150** also includes client devices **162**, which may include desktop computers, wired or wireless laptop devices, smart phones, or other computer system. The client devices **162** may include computer systems for any number of clients. Also, it should be known that any number of client devices **162** may be used for each client.

FIG. **1**C is a block diagram of an embodiment of the server **160** shown in FIG. **1**B. In this implementation, the server **160** comprises a processor **170**, a memory **172**, an interface **174**, and the database **122**. In some embodiments, the database **122** may be separate from the server **160**. The processor **170** is configured to control the operations of the server **160**. The server **160** may execute certain functions that may be stored in software and/or firmware and execute functions that may be configured in hardware. The memory **172**, in some embodiments, may comprise the web application **104** and the API **126**. The interface **174**, in some embodiments, may comprise the browser interface **124**. The interface **174** may be a network interface for interfacing with the client devices **162** via the network **156**.

The web application **104**, according to the embodiment shown in FIG. **1**A, may comprise at least a web site **120**, a database **122**, a browser interface **124**, and an Application Programming Interface (API) **126**. As shown in FIG. **1**C, the web application **104**, database **122**, browser interface **124**, and API **126** may be contained within the server **160**. The web site **120** provides various web pages and screen views (as explained below) to a user on the client system **106** or client devices **162**. The database **122** is configured to store the data retrieved from the sensing devices **102**, **152**. The database **122** may be arranged to securely separate the data for one client from another. In some embodiments, multiple databases **122** may be used. The browser interface **124** enables a user on the client system **106** to access the web site **120** and obtain sensor data formatted in an organized way, as described below. The API **126** provides an interface for the client system **106** to access the web application **104**. The web application **104**, with the web site **120**, browser interface **124**, database **122**, and API **126**, may be configured in one package, such as in a single server (e.g., server **160**).

The web site **120** can take requests from authorized clients, search the database **122**, and send information back to the clients. In some embodiments, the clients may wish to request a certain reading at a certain time and date. The log in the database **122** that is closest to that time and date can be retrieved from the database **122** and sent to the SCADA system.

Furthermore, the web site **120** may be configured to include two different types of retrieval techniques for the clients' use. The first technique is a simple Read, while the second technique is referred to ReadX. With Read, the client may make requests for data, and in response the data log is retrieved and sent back to the client. In this case, the data is merely read from the database **122** and remains in the database **122** without any change to the data entry.

However, a ReadX command allows a client to request data. Again, the data is retrieved and sent to the client. In this case, however, the web application **104** checks to ensure that the client has indeed received the data. For example, the API **126** may request for an acknowledgement from the client that the records were received successfully. When the client system **106** receives the data successfully and stores this data in its own database, it sends an acknowledgement (ACK) receipt back to the web application **104**. When the API **126** receives this ACK receipt signal, the web application **104** erases that data from the database **122**.

One benefit of the ReadX command, for example, is for security. Certain clients may not want their data to be stored on another database that does not belong to them. This may also be beneficial for the data management company that owns the server **160** or web application **104**, because the owner may be released from any liability associated with the other party's information. In this respect, the client can be able to hide or manage their proprietary data any way they see fit.

The client system **106** or client device **162** may include any suitable communication device capable of transmitting and receiving http or other data transmissions. For example, the client system **106** or client device **162** may be a personal computer, laptop computer, tablet computer, or other computer systems. The client system **106** or client device **162** may also include portable electronic communication devices, such as cell phones, smart phones, or other mobile devices that may utilize a cellular network, data network, or other types of networks. The client system **106** or client device **162** may include its own database for storing sensor data retrieved from the web application **104**. The client system **106** or client device **162** may be a Supervisory Control and Data Acquisition (SCADA) system. The client system **106** or client device **162** may also be configured to contain a user interface that allows a user to see web pages of the web application **104**, as described below with respect to FIG. **11-18**.

The system **100** may be a multi-tenant system for managing sensors for multiple clients. The system **100** may be configured to show only the sensor devices for each particular client when a client signs in. Thus, each client is only able to see their own sensors and not the sensor of other clients. However, a master device may be connected in the system **150** to allow a user to access information for all the sensors. The master device may be the server **160** that run the web application **104** or may be computer system connected directly to the server **160**. In some respects, the master device may be operated by a city or county government for monitoring the water distribution systems in their jurisdictions.

The system **100** gives clients an inexpensive product that can be employed relatively easily on the part of the client. The system **100** allows a client (e.g., water utility company) to sign up with a service that provides a combination of water monitoring functions all in one package.

The server **160** associated with the web application **104** may be configured with a system health monitoring module **180**. The system health monitoring module **180** may be configured in software, hardware, and/or firmware. The system health monitoring module **180** may be configured to evaluate the health of the water distribution system using an empirical method of analyzing many data points. The system health monitoring module **180** may be neural network for determining whether values are within a normal range. In some embodiments, the data points may be evaluated based on their location in the water distribution system and based on the time of day when the measurements were taken. The system health monitoring module **180** may use statistical analysis to determine if certain points are abnormal or unhealthy with respect to baseline data points established for a normal or healthy system.

In some embodiments, the system health monitoring module **180** may use the Mahalanobis-Taguchi System (MTS) for determining the health of the system. The MTS, for example, uses pattern recognition to analyze multivariate data. The system health monitoring module **180** can analyze values with respect to norms based on the MTS model. Not only does the MTS model diagnose the norms, but it can also include a predictive method for analyzing patterns in multivariate cases.

The system health monitoring module **180** may analyze both location-dependent and time-dependent data. For example, a water flow rate at 4:00 pm at a certain location in the water distribution system may have a certain normal range based on multiple measurements taken at this time. When values are outside of this range, the system health monitoring module **180** can instruct the interface **174** to provide an alert to the client. In some embodiments, the system health monitoring module **180** may process data stored in the database **122** from multiple sensors and consider all the parameters when diagnosing health.

The server **160** is also configured to read data in real time, perform hydraulic simulation in real-time, and recommend a pump power level in real-time. The server **160** may also read data, perform hydraulic simulation, and control the pump power level. The server **160** may also be configured to detect leaks in the main when the pressure matrix is abnormal.

FIG. **2** is a cutaway side view of a water sensing assembly **200**, according to various embodiments of the present disclosure. The water sensing assembly includes a housing **210** enclosing a battery pack **220**, a generator **230**, a pressure sensor **240**, and measurement and communication electronics **250**. An antenna **260** is mounted to the exterior of the housing **210**. Extending from a lower end of the housing **210** is a turbine **270**. The turbine **270** is a vertical axis turbine in the current embodiment, and is coupled to the generator **230** by a turbine shaft **275** extending through a sealed shaft bore **277** and a seal partition **279** to connect with a generator shaft **235** of the generator **230**. In various embodiments, the turbine **270** is may be indirectly coupled to the generator, such as with magnets, so that the turbine **270** may be fully separated from a sealed interior of the housing **21**.

The pressure sensor **240** is mounted within the housing **210** such that the pressure sensor **240** extends through the seal partition **275** to partially expose pressure sensor **240** to fluid flow along the lower end of the housing **210**, which may travel around turbine **270** into the lower interior of housing **210**. The pressure sensor **240** communicates fluid pressure readings to measurement and communications electronics **250**, which may process, store, and/or communicate the date through antenna connection **260**. The measurement and communications electronics **250**, pressure sensor **240**, and antenna **260** are powered by battery pack **220**, which is recharged by generator **230**.

In operation, the water sensing assembly **200** is a self-contained, removable sensing unit that may be tapped into a fluid pipe or other valve through a tap or bore. The turbine **270** is situated such that the turbine **270** is within the fluid path of the fluid passing through the fluid pipe. The fluid flow thereby turns the turbine **270**, turning the generator shaft **235**, causing the generator **230** to generate a current to recharge batter pack **220**. The presence of the turbine **270** and generator **230** attached to the battery pack **220** allows the battery pack **220** to last longer, giving the water sensing assembly **200** a longer life to detect sensing data. The pressure sensor **240** may be replaced by various other sensors in various embodiments, such as chlorine or flow sensors.

FIG. **3**A is detail view of the shape of a vertical axis turbine **370**. As seen in FIG. **3**A, the vertical axis turbine **370** includes two wings **372***a,b*, each wing having a curved profile and extending in opposite spirals on either side of a central turbine axis **374**. When fluid flows in against vertical axis turbine **370** in a direction **376** orthogonal to the central turbine axis **374**, fluid pushes wings **372***a,b* such that the vertical axis turbine **370** spins about central turbine axis **374**.

FIG. **3**B is a perspective view of a second water sensing assembly **300**, according to various embodiments of the present disclosure. The water sensing assembly **300** includes a housing **310**, a mounting bracket **320**, mounting bracket fasteners **325**, power wires **330**, and a turbine **340**. As seen in FIG. **3**B, the housing **310** is coupled to the mounting bracket **320**, and power wires **330** extend through a wiring bore **322** defined in the mounting bracket **320** into housing **310**.

FIG. **3**C is another cutaway side view of the second water sensing assembly **300** of FIG. **3**B, according to various embodiments of the present disclosure. As seen in FIG. **3**C, a generator **350** is mounted within the housing **310** similarly to generator **230**. The turbine **340** extends from a lower end of the housing **310** similarly to turbine **270**. The turbine **340** is a vertical axis turbine in the current embodiment, and is coupled to the generator **340** by a turbine shaft **345** extending through a sealed shaft bore **347** and a seal partition **349** to connect with a generator shaft **355** of the generator **350**. A side bore **380** is defined in the housing **310** below seal partition **349** so that fluid may flow around turbine **340** to side bore **380**. In various embodiments, the turbine **340** is may be indirectly coupled to the generator, such as with magnets, so that the turbine **340** may be fully separated from a sealed interior of the housing **310**. In the current embodiment, the power wires **330** may be directly connected to the generator to power sensing, communication, process, data storage, and other electronic equipment. Further, a pressure sensor or other sensor may be mounted within the housing **310** similarly to pressure sensor **240** within housing **210**.

The mounting bracket **320** may mount the water sensing assembly **300** on any sort of sensing, tapping, or boring equipment.

FIG. **4** is a diagram of the water sensing assembly **400** of FIG. **2** installed on a pipe, with various partial cross-sectional views of parts of the water sensing assembly **400** and the surrounding environment, according to various embodiments of the present disclosure. The water sensing assembly **400** is buried underground in the current embodiment such that it extends from a pipe **410** to a ground surface **420**, such as a road.

FIG. **5** is front cross-sectional view of the water sensing assembly **400** of FIG. **4**, according to various embodiments of the present disclosure. As seen in FIG. **5**, the water sensing assembly **400** includes a valve box **1** mounted over pipe **4**. A saddle **15** connects ball valve **6** to the pipe **4**, and a reducer **5** couples a pressure sensor **7** to the ball valve **6**. Wiring **11** runs up through the valve box **1** to a communication assembly **17**. The communication assembly **17** may contain processing, data storage, and power equipment in various embodiments to store, communicate, and receive orders based on data received from the pressure sensor **7**. To communicate data and receive orders, the communication assembly **17** is connected by a wire **14** to an antenna **2** mounted on an iron cap **18**, the iron cap **18** itself mounted on an adjustable top **3**. The adjustable top **3** connects to the valve box **1**, forming an enclosure extending from ground surface **420** to the top of pipe **410** to protect the enclosed equipment. The adjustable top **3** can be adjusted telescopically to vary the overall height of the water sensing assembly **400**, based on the depth of the pipe below ground level. Other sensors may be used with water sensing assembly, such as chlorine or flow sensors.

FIG. **6** is a partially cutaway side view of the water sensing assembly **400** of FIG. **4**, according to various embodiments of the present disclosure. As seen in FIG. **6**, the communication assembly **17** is mounted to the iron cap **18** by a hanging bracket **16**. The communication assembly **17** is configured to receive measurement signals from the _ and transmit the signals from antenna **2** of the sensor assembly. The signals are transmitted to the web application **104** via the cellular network **116** or **154**. The antenna **2** may be configured for Global System for Mobile (GSM) communication using a cellular network, Code Division Multiple Access (CDMA) communication, or can be used with other types of communication networks and protocols. In some embodiments, the communication device **17** may include a plug-in for Wi-Fi, Bluetooth, or other short range communication.

FIG. **7** is an exploded view of the water sensing assembly **400** of FIG. **4**, according to various embodiments of the present disclosure. As shown in FIG. **7**, the water assembly **400** includes two flat washers **8**, lock washer **9**, two hex nuts **10**, hanging bracket **16**, machine screw **12**, and jam nut **13**, the combination of which mounts communication assembly **17** to iron cap **18**.

FIG. **8** is a cutaway side view of a water sensing assembly **300** mounted in a multi-port service saddle **800** on a pipe **810**, according to various embodiments of the present disclosure. As shown in FIG. **8**, the multi-port service saddle **800** includes a main port **820** and a secondary port **830**. A ball valve **840** is mounted in main port **820** and a ball valve **850** is mounted in secondary port **830**. Ball valve **840** includes a ball bore **842** and ball valve **850** includes a ball bore **852**, each of which may be turned to open and close main port **820** and secondary port **830**, respectively. In FIG. **8**, the ball valve **840** is closed and the ball valve **850** is open. A lower end **860** of the multi-port service saddle **800** defines a lower opening **862**, which is aligned with a bore **812** in the pipe **810**.

To form bore **812** in the pipe **810** without leakage from the pipe, the multi-port service saddle **800** is mounted to the pipe exterior with the ball valve **840** open and the ball valve **850** closed. A tapping machine is mounted to main port **820** and is pushed down through main port **820** to form bore **812**. The tapping machine is then pulled out of ball valve **840** into a pre-insertion position and ball valve **840** is closed. Water sensing assembly **300** may then be mounted to multi-port service saddle as shown in FIG. **8**.

As shown in FIG. **8**, water sensing assembly **300** is mounted to a port bracket **890** coupled to main port **820**. Insertion screws **870** extend between mounting bracket **320** and port bracket **890**, with turbine **340** and housing **310** pre-inserted into main port **820**. A sensor cap **880** is shown coupled to secondary port **830** and including a sensor **882**. Sensor **882** can be any sensor for fluid data collection, such as a pressure sensor, chlorine sensor, or flow sensor. While the water sensing assembly **300** is mounted outside ball valve **840**, fluid may flow into multi-port service saddle **800** to secondary port **830** where the fluid may be sensed by sensor **882**.

FIG. **9** is a cutaway side view of the second water sensing assembly **300** in a power generation mode, according to various embodiments of the present disclosure. To place water sensing assembly **300** in power generation mode, ball valve **840** is opened and insertion screws **870** are tightened to pull mounting bracket **320** towards port bracket **890**. Once mounting bracket **320** and port bracket **890** are flush together, as shown in FIG. **9**, mounting bracket fasteners **325** fasten mounting bracket **320** to port bracket **890**. However, in various embodiments, water sensing assembly **300** may be inserted to various degrees within main port **820** such that turbine **340** may be partially presented at varying depths to fluid flow within pipe **810**, which may lessen the speed at which turbine **340** turns, generating less power and allowing for a customizable level of power generation based on known fluid flow and power needs. Moving mounting bracket **320** towards port bracket **890** inserts housing **310** and turbine **340** into main port **820** such that turbine **340** extends down through lower opening **862** bore **812** into fluid flow within pipe **810**, thereby turning turbine **340** and generating current to power various equipment or recharge batteries. In this configuration, fluid flow may pass up through side bore **380** so that sensor **882** may continue to sense fluid conditions within pipe **810**. Turbine **340** may be removed from the fluid path within pipe **810** by use of insertion screws **870** to move mounting bracket **320** away from port bracket **890**. This may be necessary if, for instance, a pig is sent down the pipe **810** to clean the system and it is desired to prevent damage to turbine **340**.

FIG. **10** is a chart showing an exemplary sampling rate, log rate, and upload rate related to sensing water properties. The sensing assembly may be configured to remain in a sleep mode until it is configured to wake up and take a sample reading. For example, the sampling rate may include sampling once every 15 seconds. The log rate may be set, for example, at about once every 15 minutes. During the log interval (e.g., 15 minutes), the processing device of the sensor assembly may be configured to store only the samples that are the highest value and the lowest value. Measurements in between the high value and low value during that log interval may be discarded. When a new high or new low value is sampled, it replaces the old value. In this sense, only two values are stored during each log interval. At the end of the log interval, the processing device stores the high and low value for that interval in memory. Therefore, at the log rate (e.g., once every 15 minutes), two values are stored or logged. The sensor assembly repeats the logging at the log rate until it is time for uploading as determined by the upload rate. In one example, the upload rate may be about once per day. This is the rate at which the sensor assembly uploads the log information via the antenna **114** to the server **160**.

One benefit of these three rates is that the sensor data does not consume much memory within the sensor assembly, only the high and low values for each log interval. Also, the upload rate may be set to upload not very often (e.g., once a day), which can conserve battery life versus uploading after every reading. Thus, the sensor and communication device **17** may be in a sleep mode and then wake up only to sense and upload data. For example, with these rate settings, a battery may last about seven years or longer.

In some embodiments, the sampling rate and log rate may be set to the same rate. A client may request such a set-up if they wish to view the data in more detail and have access to the data at any time. The cellular modem may be placed in a low-power mode and listen for a signal, such as an SMS message from the client. In this way, the client can get a substantially real-time measurement. When requested in this manner, the sensor assembly is waken up, regardless of the sampling rate times, and takes a reading. The communication device sends the newly taken reading, or, in some embodiments, may send the high and low readings of a current logging interval, to the web application **104**. The web site **120** can then communicate that data directly to the client, via e-mail, SMS, or other communication channel. Of course, this strategy may increase the battery usage compared with normal operations. This may cut the battery life to about two years.

The client may be given options to choose between different types of plans for receiving sensor data. For example, the client may wish to have access to data under normal operations, with the uploaded data being available the following day. The second option may be the substantially real-time plan.

Another feature of the sensor assembly is that when sample data is measured, the processing device may analyze the data to see if it falls within a normal range of values. If so, then nothing needs to be done, except store the values if they are highs or lows for the period. Otherwise, if the values are not within normal range, the communication device sends an alert to the web site **120**. In this case, the modem is waken from sleep mode and instructed to transmit the details of the out-of-range measurement. In response to receiving this alert, the web site **120** may be configured to check the reading with the client's settings to find out what type of notification they wish to receive when such a condition occurs. The web site **120** may then send an SMS message, e-mail, or other type of message to inform the client of the condition.

FIGS. **11-18** show examples of various screen views of web pages that may be displayed on a user interface, such as the user interface of the client system **106**. The web pages may be part of the web site **120** shown in FIG. **1** that allows a client to access the data stored in the database **122**. The web pages are designed to provide an organized and easy to understand display for the users.

FIG. **11** is an example of a screen view of a web page that may be displayed on a user interface **1100** for enabling a user to sign up to receive a service for viewing water property data. Initially, a new user signs up or registers with the web server. After the user is registered, he or she can sign in to the server and obtain the relevant data. For example, the web server may include the one or more web servers that are configured to run the web application **104** shown in FIG. **1**. In this respect, the user interface **1100** may be displayed on a screen, display, monitor, or other visual indication device of the client system **106**. The user interface **1100** allows a user to sign up using an e-mail address, password, first name, last name, and mobile phone number.

Also, the sign up user interface **1100** includes an entry window for a "service contract number." The service contract number is a number that is set up for a particular client that has a service contract with the company that manages the web application **104** shown in FIG. **1**. A client may allow its associates or employees to also sign up to gain access under the respective service contract number.

The user interface **1100** also includes entry windows for time zone, street address, city, state, and zip code. This can be the information for the location of the client (e.g., water distribution company).

In addition, the user interface **1100** includes four selectable boxes that allow the new user to set up the types of ways that the user may be contacted if a warning condition or critical condition occurs. For example, the user may choose to receive a text message (e.g., a Short Message Service (SMS)) message or other type of electronic message on a portable electronic device. The user may also choose to receive an e-mail message for warning or critical conditions. For example, a warning condition may be a condition that if untreated may lead to problems with the water distribution system, while a critical condition may be a condition that indicates a more severe problem, such as pipe that has burst.

One method for initiating a new contract according to one implementation may include the following. The data managing company provides a service contract number to a new client. They also send the client a URL and instructions on how to set up an account. The URL and instructions are contained in an e-mail that is sent to the client. A contact person (e.g., a boss) at the client's company may set up a profile for himself or herself. He or she may also send the URL and instructions to other in the company so that they too can set up a profile. The additional profiles will include the personal information for the other people (e.g., employees) and will also include the same service contract number for that company. Each individual in the company can therefore choose the types of notifications they receive when a warning condition or critical condition is sensed.

FIG. **12** is an example of a screen view of a web page that may be displayed on a user interface **1200** showing a map of sensing device locations. The map may be any suitable map of an area where a client's sensing devices are installed. Sensors may be installed in any part of the water distribution system, such as on main pipes, secondary pipes, neighborhood pipes, residential pipes, etc. For example, the map may be provided by Google Maps or other online mapping service.

Superimposed on this map are icons **1202**, which are configured to display the locations of the sensor devices **102**. As shown in this figure, five icons are displayed, representing five different sensor devices **102**. It should be understood that the map may show any number of icons **1202**, depending on how many sensor devices are installed and placed in service. The icons **1202** can each include a number for distinguishing one sensor from another. If a user selects one of the icons, such as by hovering a mouse icon over an icon **1202**, clicking an icon **1202**, tapping an icon **1202** on a touch-sensitive screen, or by other entry methods, the web site **120** may be configured to bring up a new page, such as the page described with respect to FIG. **13**.

The icons **1202** can be displayed in different ways to indicate various conditions of the sensor. For example, if the sensor senses a warning condition, the icon **1202** may be displayed in a different way from a normal condition. In one embodiment, the icons **1202** may be green if they measurements are within a normal range, but may be changed to yellow or red if the measurements indicate a warning or critical condition. Other than changing color to indicate condition, the icons **1202** can also be displayed in other ways, such as by changing the size or shape of the icon **1202**, or by flashing the icon **1202**, or other means of distinguishing an abnormal condition from a normal one.

The user interface **1200** may be configured to show different types of sensors. For example, if a client has any combination of pressure sensors, flow rate sensors, chlorine sensors, etc., each type of sensor may be displayed differently. As an example, the different types may be distinguished by using different colors (e.g., blue, green, black, etc.) for the icons. The different sensors may also be shown with icons of different shapes (e.g., circle, square, triangle, etc.).

FIG. **13** is an example of a screen view of a web page that may be displayed on a user interface **1300** showing a map of sensing locations with information about a sensing device superimposed. In this example, the information for the selected sensor is displayed in a box **1302**, representing a device condition window. The information may include a current reading for that sensor. With respect to implementations in which the sensing device is a pressure sensor, the reading may give a value in units of pounds per square inch (psi). The illustrated example shows a current pressure of 40.0 psi. If the sensor is configured to measure chlorine content, for instance, the box **1302** may display "Chlorine Content" with the reading.

If the reading (e.g., pressure) is out of a normal range, then the numbers may be highlighted in a particular way to draw attention to it. For example, the number may appear in yellow if the reading is within a warning level and may appear in red if it is within a critical condition. Also, green may be a color used to indicate that the reading is normal.

The box **1302** may also include a phone number of the device **102**, which may be the cellular number used to communicate the data to the cellular network **116**. The box **1302** may also include an address of the device **102**.

The superimposed box **1302** may also include a first link to "Device" and a second link to "Measurements." The first link allows a user to navigate to another web page, such as the web page described with respect to FIG. **14**. The second link allows the user to navigate to yet another web page, such as the web page described with respect to FIG. **16**.

FIG. **14** is an example of a screen view of a web page that may be displayed on a user interface **1400** showing further details of a sensing device. For example, this web page may be displayed when the user selects the "Devices" link shown in FIG. **13** or when the user navigates to the page by some other route. The user interface **1400** shows more details of the particular sensing device highlighted at an earlier time. The device information may include the phone number, a description of its location, latitude and longitude information, high warning level, critical high level, low warning level, and critical low level. The information may also include a reading of a particular property (e.g., pressure). The measurement value (e.g., pressure) may be highlighted in any suitable way if the value is outside of the range indicated by the high and low warning levels or outside the range indicated by the high and low critical condition levels.

The high warning level, critically high level, low warning level, and critically low level may be set by the client, having an understanding of the nature of the various pipes throughout the water distribution system. For example, a high warning level of 110.0 psi is a level that the client knows may be an indication of a problem that should likely be investigated. A critically high level of 150.0 psi is likely an indication that a pipe is about to burst. A low warning level of 40.0 psi may indicate a small leak in the pipe, and a critically low level of 30.0 psi may indicate a larger leak that likely needs to be attended to immediately. Also, when a critically low level occurs in a pressure reading, the client may need to notify its customers of a "boil" notice that water may be engraphed with contaminates.

A "status" output may also be displayed. If status is normal, the output may be blank, but if the status is a warning or critical, the status indication may be changed to show such conditions. For example, the status may change to a different color, may blink, or may include some other type of highlighting feature. In one embodiment, for a warning, the status output may be displayed yellow, and for a critical condition, the status output may be displayed red.

FIG. **15** is an example of a screen view of a web page that may be displayed on a user interface **1500** for enabling a user to edit parameters of a sensing device. In this web page, the user can change the description, which may include location information of the device. The user can also change the latitude and longitude information, and the high and low warning and critical condition levels. When finished editing, the user can click on the "update device" button. In some embodiments, the phone number box may not be available to the client but may only be available for users of the management company.

FIG. **16** is an example of a screen view of a web page that may be displayed on a user interface **1600** showing a graph and data points representing measurements by a sensing device. This web page shows measurement data from one sensor over certain time periods. The user may select time periods of 1 day, 2 days, 5 days, 1 week, 2 weeks, 1 month, 6 months, 1 year, or all. The graph section of the web page shows the high and low points for each day. The data point section shows the reading (e.g., pressure), notes (if any), and the time when the measurement was taken. This web page also gives the user an option to edit or annotate a particular record by pressing the "edit" button on the same line as the record.

The data points in the graph and in the table may be highlighted in any suitable way to indicate when a measurement is outside a range of normal limits. For example, the date points or measurement readings may be given a different color, size, shape, or other distinctive feature to indicate abnormal conditions.

FIG. **17** is an example of a screen view of a web page that may be displayed on a user interface **1700** for enabling a user to edit measurements. For example, if the user of the user interface **1600** of FIG. **16** presses the "edit" button, the web site **120** navigates the user to the user interface **1700**. In this page, the user can enter a note that is saved with the particular data record. In this example, the user wishes to annotate a low pressure reading that occurred when the client was aware that a pipe was broken. In this case, the user enters a message, such as "Main Pipe was broken." To enter the new note into the database **122**, the user selects the "update measurement" button. In some embodiments, the "destroy" button may not be available or may be available to a limited extent. The purpose of the destroy button is to remove the particular sensor from the system and/or ignore any readings or communications from the sensor.

FIG. **18** is an example of a screen view of a web page that may be displayed on a user interface **1800** for enabling a user to edit user information. The user interface **1800** in this example is similar to the user sign-up page shown in FIG. **11**. A user can access this page using the "Edit Profile" link on any of the user interfaces shown in FIGS. **12-18**. The user can edit any information, such as e-mail, address, password, or other personal information. The user can also edit the ways that the user will receive warnings from the system **100**. For example, if the user decides that he or she wants to receive both an SMS message and an e-mail when there is a critical condition, the user can check the appropriate boxes.

The server **160** may be part of the utility company (e.g., water utility company) and provide communication with other users via the communication network. In some embodiments, the server may be part of a company responsible for managing the utility measurement data. The communication network in these embodiments may be a local area network (LAN), wide area network (WAN), such as the Internet, or any other suitable data communication networks. The communication network may also include other types of networks, such as plain old telephone service (POTS), cellular systems, satellite systems, etc.

The server **160** may detect extreme events and provide an alarm in response. The alarm may be in the form of an automated e-mail, a pop-up window, an interrupt signal or indication on a computer of the client device **162**, SMS, or other suitable message signifying an urgent event.

The client system **106** may include a computer system used by the utility provider. In this respect, the utility provider system may be a client of the data management company that manages the utility measurement data and/or provides monitoring services regarding the status of the utility infrastructure. The client system, therefore, may be able to receive and review status updates regarding the infrastructure. Alarms may be provided to the client system, which may then be acknowledged and confirmed. The client system may also receive historic data and manage the client's accounts and usage information. In some embodiments, information may be provided to the client system in a read-only manner.

The sensing devices **152** and client devices **162** may communicate with the server **160** by a cellular service, via cellular towers and/or satellites. The wireless communication between the devices may be active during some periods of time (when two respective devices are linked) and may be inactive during other periods of time (when the devices are not linked and/or are in sleep mode). Alternatively, any of the sensing devices **152** may be connected to the network **156** through wired connections.

The water mains may include transmission mains, which may include water pipes having an inside diameter of at least twelve inches. The water mains also include distribution mains, which may include smaller pipes having an inside diameter of less than twelve inches. The transmission mains, having a greater size, may be configured to allow a greater amount of water flow in comparison with the distribution mains. The transmission mains may be located nearer to the utility source and the distribution mains may be located farther from the utility provider. In some systems, distribution mains may be located along secondary roads or residential roads.

The cellular network **116** may include relay devices (e.g., using ISM frequency transmission) for relaying radio signals from the cell towers **154** to the data network **156**. The network **156** in some embodiments may also include the cellular network **116**, a satellite network, a radio network, a LAN, a WAN, or any other suitable network.

In some embodiments, the sensing devices **152** may comprise printed circuit board with the components of a sensor interface, processing device, and communication device incorporated on the printed circuit board. In other embodiments, multiple printed circuit boards may be used with the components of the sensor interface, processing device, and communication device incorporated on the boards in any suitable configuration. When the electrical components are disposed on multiple boards, standoffs may be used as needed. Connectors may be used to couple the processing device with the sensor interface and communication device.

The sensor assembly may include any combination of sensors for detecting various parameters that may be analyzed. For example, the sensor assembly may include one or more piezoelectric sensors, acoustic sensors, acoustic transducers, hydrophones, pressure sensors, pressure transducers, temperature sensors, accelerometers, flow sensors, chlorine sensors, leak detectors, vibration sensors, or other types of sensors.

The power supply of the sensor assembly may contain one or more batteries, solar-powered devices, electrical power line couplers, or other power sources. When external power is received, additional connectors or ports may be added through the walls of the enclosure. When batteries are used, the power supply may also include a battery capacity detection module for detecting the capacity of the one or more batteries. In some embodiments, the power may be partially or completely supplied by the energy harvesting device housed on the sensor assembly itself.

A sensor interface may be incorporated in the sensor assembly. The sensor interface may be configured to acquire the acoustic, pressure, and/or temperature data from the sensor assembly. In addition, the sensor interface may include amplification circuitry for amplifying the sensed signals. The sensor interface may also include summing devices, low pass filters, high pass filters, and other circuitry for preparing the signals for the processing device. The sensor assembly may also include a processing device configured to log the measurement information and save it in memory until a designated upload time or when requested by a client.

The communication device of the sensor assembly may include a modem, such as a cellular or ISM-enabled modem to provide network access to the communication device. Also, the communication device may include a tuning module, such as a GPS timing receiver, for providing an accurate timing reference and for synchronizing timing signals with other elements of the cellular network **116**. The communication device may be configured to transmit and receive RF signals (e.g., ISM frequency signals), cellular signals, GPS signals, etc., via the antenna **114**.

The processing device housed in the sensor assembly may include a processor, a sensor data handling device, a power assembly, a communication module, a time/sleep module, a data processing module, a health status detecting module, and a storage module. The processor may comprise one or more of a microcontroller unit (MCU), a digital signal processor (DSP), and other processing elements.

The sensor data handling device connects with the sensor interface and handles the sensor data to allow processing of the signals by the processor. The power assembly may comprise a power source, which may be separate from the power supply. In some embodiments, however, the power assembly may be connected to the power supply. The power assembly may also be configured to control the voltage and current levels to provide constant power to the processor. In some embodiments, the processor may be provided with about 3.3 volts DC. The communication module connects with the communication device and receives and/or sends signals for communication through the communication device. In some embodiments, the communication device may include a GPS device for receiving timing samples for synchronization purposes. The timing samples may be forwarded to the communication module to allow the processing device to be synchronized with other devices. The timing samples may also be used to wake up the processing device when needed or sleep when inactive.

The processing device also includes a time/sleep module for providing timing signals to the processor and may include a crystal oscillator. The time/sleep module also controls sleep modes in order to minimize battery usage when the sensor assembly is not in use. For example, the processor may include an MCU that operates continually and a DSP that sleeps when not in use. Since the DSP normally uses more power, it is allowed to sleep in order to conserve battery power.

The time/sleep module may be configured to wake various components of the processor at designated times in order that sensor data stored during a previous time may be transmitted to the host. In some embodiments, the time/sleep module may wake the sensor assembly at a certain time during the day, enable the sensor assembly to analyze and record the measurements, return to a sleep mode according to the sampling rate, and repeat the analysis every 15 seconds or so for about 15 minutes. At the end of log period, the communication device sends the data to the server **160** and the time/sleep module returns the device to a sleep mode until the next designated time. Separate from the regular sensing schedule, the time/sleep module may be configured to wake up the processor in the event that a warning or critical condition has been detected.

The storage module of the sensor assembly may include flash memory, read-only memory (ROM), random access memory (RAM), or other types of memory.

Pressure sensors may be used in particular to measure an absolute pressure value. Also, pressure sensors may be used as a burst sensor. In this respect, the sensor may measure a high-speed pressure transient profile. Both the pressure change value and absolute pressure value may be useful for different applications. The sensor(s) may measure voltage signals or frequency measurements. Temperature sensors may also be used for measuring the temperature of the pipe. The sensed waveform signals are supplied to the processing device, which may process the signals at the point of measurement. In other embodiments, the signals may be transmitted to the host for processing.

It should be noted that the functions of the sensor assembly may be configured in software or firmware and the functions performed by the processor. The processor, as mentioned above, may include a DSP, microcontroller, or other types of processing units. In some embodiments, the signals may be communicated to the server **160** where processing may occur. The real time processing may be performed by a DSP, for example.

One should note that conditional language, such as, among others, "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more particular embodiments or that one or more particular embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

It should be emphasized that the above-described embodiments are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Any process descriptions or blocks in flow diagrams should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included in which functions may not be included or executed at all, may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. Further, the scope of the present disclosure is intended to cover any and all combinations and sub-combinations of all elements, features, and aspects discussed above. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure.

The invention claimed is:

1. An analysis system comprising:

a plurality of water sensors connected at various points to a water distribution system, each of the plurality of water sensors configured to

periodically sample a property of water according to a sampling rate,

determine whether each sampled value of the property of water represents a highest value or a lowest value of the property of water in a plurality of samples taken during a current log interval according to a log rate,

store only the highest value and the lowest value of the property of water for the current log interval, and

periodically upload to a computer server highest values and lowest values of the property of water for each of a plurality of log intervals according to an upload rate, wherein the log rate is distinct from and smaller than the sampling rate, and the upload rate is distinct from and smaller than the log rate;

the computer server configured to communicate with the plurality of water sensors via a network and receive the highest values and the lowest values of the property of water for the plurality of log intervals from the plurality of water sensors, the computer server comprising:

a processor,

a database configured to store the highest values and the lowest values of the property of water for each of the plurality of log intervals from the plurality of water sensors, and

a system health monitoring module configured to evaluate the health of the water distribution system based on an analysis of the stored highest values and the lowest values of the property of water for each of the plurality of log intervals to obtain health data; and

at least one client device configured to communicate with the computer server via the network and receive the health data from the computer server.

2. The analysis system of claim **1**, wherein the computer server further comprises a memory configured to store a web application having web site logic.

3. The analysis system of claim **1**, wherein the system health monitoring module is configured to use empirical methods for analyzing the highest values and the lowest values of the property of water from the plurality of water sensors to evaluate the health of the water distribution system.

4. The analysis system of claim **1**, wherein the system health monitoring module is a neural network.

5. The analysis system of claim **1**, wherein the system health monitoring module is configured to evaluate the health of the water distribution system based on a location of each of the water sensors within the water distribution system and a time of day when the highest values and the lowest values of the property of the water were obtained.

6. The analysis system of claim **1**, wherein the system health monitoring module is configured to use statistical analysis to determine if data points of the highest values and the lowest values of the property of the water are abnormal with respect to baseline points.

7. The analysis system of claim **1**, wherein the system health monitoring module is configured to use the Mahalanobis-Tagushi System (MTS) for determining the health of the water distribution system.

8. The analysis system of claim **7**, wherein the system health monitoring module is further configured to use pattern recognition to analyze multi-variate data.

9. The analysis system of claim **7**, wherein the system health monitoring module is further configured to use a predictive method for analyzing patterns in the highest values and the lowest values of the property of the water.

10. The analysis system of claim **1**, wherein the computer server is configured to read the highest values and the lowest values of the property of the water in real-time.

11. The analysis system of claim **1**, wherein the computer server is configured to perform hydraulic simulation.

12. The analysis system of claim **1**, wherein the computer server is configured to control pump power levels.

13. A method of sensing a property of water within a water distribution system, the method comprising the steps of:

periodically sampling, by a processing device of a sensor assembly, a value for the property of water according to a sampling rate such that multiple values are obtained during each of a plurality of logging intervals, a length of each of the plurality of logging intervals based on a log rate;

determining, by the processing device, whether each sampled value is a highest value or a lowest value of the property of water in the multiple values obtained during a current logging interval of the plurality of logging intervals;

storing, by the processing device, only the highest value and the lowest value of the property of water in a memory of the sensor assembly for each of the plurality of logging intervals; and

periodically uploading, by the processing device, the highest values and lowest values for each of the plurality of logging intervals from the memory to a server for analysis according to an upload rate, wherein the log rate is distinct from and smaller than the sampling rate, and the upload rate is distinct from and smaller than the log rate.

14. The method of claim **13**, further comprising the step of discarding an intermediate value when the sampled value of the property of water falls between the highest value and the lowest value for a current logging interval.

15. The method of claim **13**, wherein determining whether each sampled value is the highest value of the property of water in the multiple values obtained during a logging interval comprises the steps of:

replacing a previous highest value stored at an earlier time with a new highest value when a sampled value of the property of water is higher than the previous highest value; and

discarding the previous highest value.

16. The method of claim **13**, wherein determining whether each sampled value is the lowest value of the property of water in the multiple values obtained during a logging interval comprises the steps of:

replacing a previous lowest value stored at an earlier time with a new lowest value when a sampled value of the property of water is lower than the previous lowest value; and

discarding the previous lowest value.

17. The method of claim **13**, further comprising the steps of:

determining if a sampled value of the property of water is outside of a normal range; and

sending an alarm signal to notify a user that the sampled value of the property of water is outside the normal range.

18. The method of claim **13**, wherein a communication assembly utilized to upload the highest values and lowest values for each of the plurality of logging intervals to the server is in a sleep mode between each uploading.

19. The method of claim **13**, further comprising:

analyzing the highest value and lowest value for each of the plurality of logging intervals to determine if the two values are within a normal range of values; and

if either of the two values are not within the normal range, communicating at least one of the two values to a web site, the web site configured to send a notification to a user.

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